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August 1996

US Army Corps of Engineers
Waterways Experiment Station

Observations and Modelling of Winds and Waves During the Surface Wave Dynamics Experiment

Report 4
ROWS Wind and Wave Observations
12 February - 7 March 1991

by Frederick C. Jackson

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Prepared for Headquarters, U.S. Army Corps of Engineers
and National Aeronautics and Space Administration,
Goddard Space Flight Center

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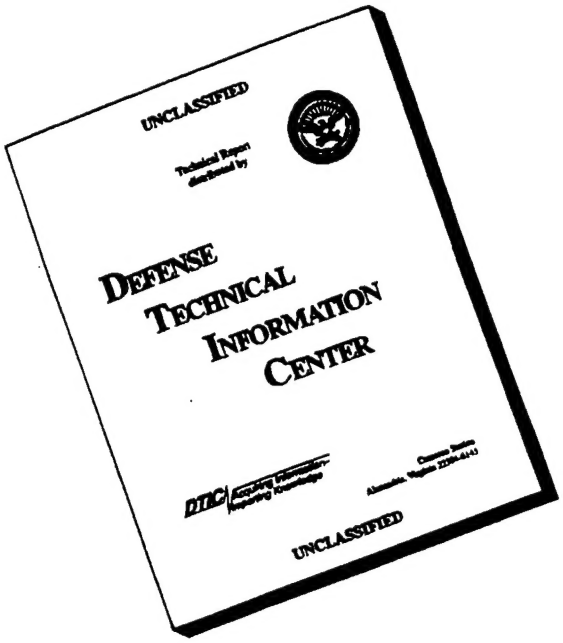

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by Frederick C. Jackson

218 North Pitt Street
Alexandria, VA 22314

Report 4 of a series

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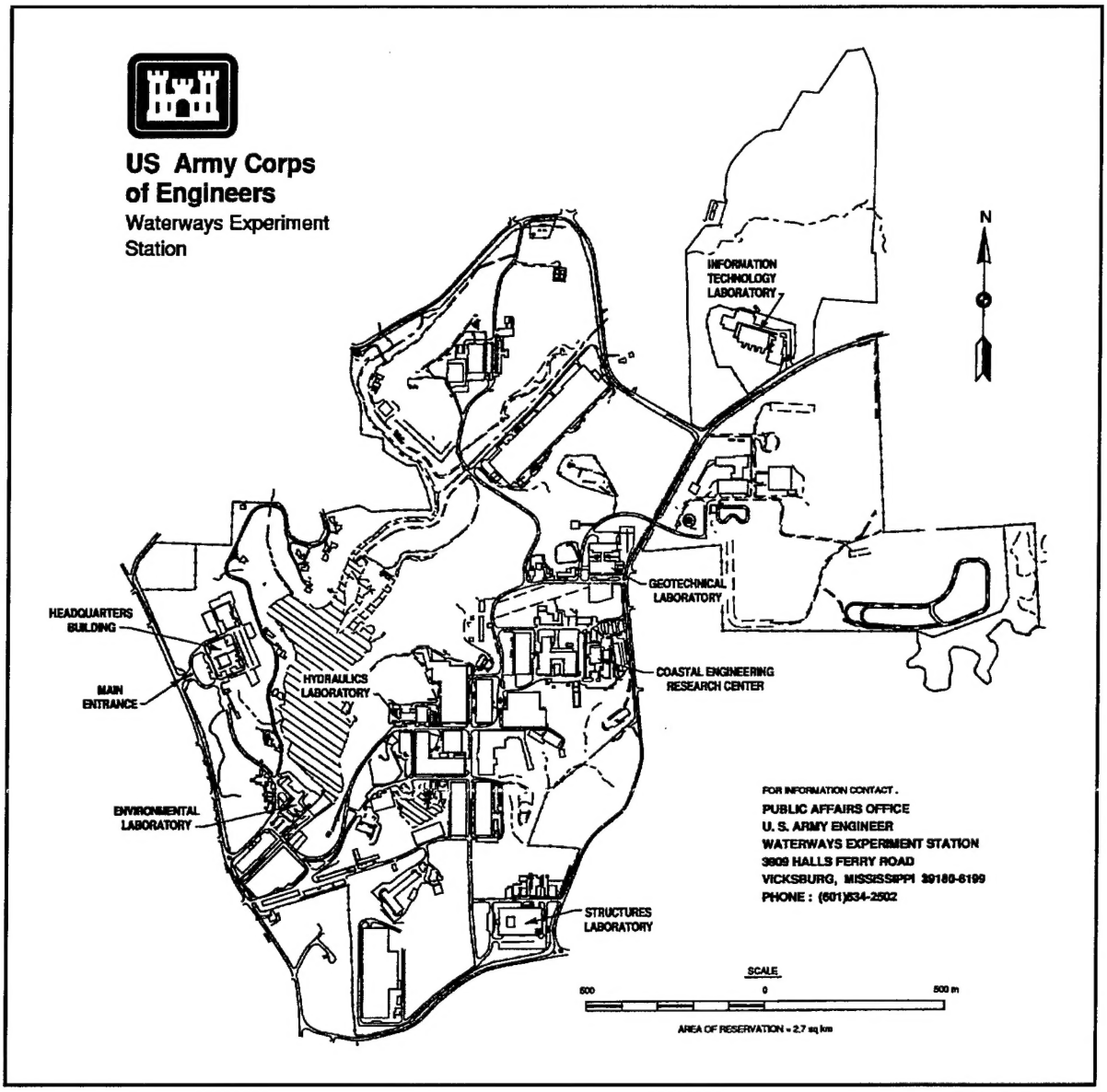

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Preface

The airborne Radar Ocean Wave Spectrometer (ROWS) data presented in this report were collected by the author as part of the National Aeronautics and Space Administration's (NASA's) contribution to the Surface WAve Dynamics Experiment (SWADE). Funding for the aircraft flights was provided jointly by NASA and the U.S. Army Corps of Engineers (USACE). Thanks are due Dr. C. Linwood Vincent for the USACE contribution to the funding of these flights.

The successful ROWS flight campaign in SWADE would not have been possible without the support of a number of NASA/Wallops Flight Facility (WFF) personnel. Aircraft flights were conducted over a 2-month period—days, nights, and weekends—often on short notice according to the vagaries of the weather and often under trying circumstances. Among the aircraft support personnel involved in the ROWS flights, the author acknowledges particularly the support of Mr. Peter Bradfield, the flight coordinator, and Mr. Robert Gidge, the pilot of the NASA 431 for most of the ROWS SWADE flights.

Engineering and technical support for the ROWS instrument were provided by Mr. Douglas Vandemark and Mr. Donald Hines. Mr. John Ward and Mr. Steve Bailey were responsible for developing the new PC-based data acquisition system for the ROWS. Dr. Charles Vaughn developed new ROWS preprocessing software. Mr. Doug Vandemark and Dr. Bertrand Chapron (SM Systems and Research Corporation) developed a new code for the ROWS production data processing. Ms. Karen Stewart (Computer Sciences Corporation) carried out the production data processing. Mr. David Oberholtzer helped produce ROWS flight line maps. The cooperation of all these individuals would not have been possible without the full support of the head of the Observational Sciences Branch (Code 972), WFF, Mr. David Clem. The author thanks Mr. Clem for hosting him during his year's stay at WFF. Mr. Clem is also to be acknowledged and thanked by all SWADE participants for his hosting of SWADE meetings at WFF and for his logistical support during all phases of the experiment.

ROWS data collection strategy in the early part of the mission (i.e., prior to the third Intensive Operational Period) was developed jointly between the author and Dr. Robert Jensen of the U.S. Army Engineer Waterways Experiment Station (WES). This collaboration resulted in some of

the best data collected in SWADE; namely, the ROWS data collected during the "St. Valentine's Day" wind/wave episode. Dr. Jensen provided the author with a number of data sets generated by others, including the numerical data products of Dr. William Gemmill of the National Oceanic and Atmospheric Administration/National Weather Service/National Meteorological Center (surface winds) and the U.S. Navy's Fleet Numerical Meterology and Oceanography Center (current fields). Throughout the course of this work, Dr. Jensen has provided guidance and encouragement, for which the author is most grateful. Dr. Jensen's work was carried out under the supervision of Mr. H. Lee Butler, Chief, Research Division; and under the general supervision of Dr. James R. Houston and Mr. Charles C. Calhoun, Jr., Director and Assistant Director, Coastal Engineering Research Center, respectively

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

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1 Introduction

The Surface WAve Dynamics Experiment (SWADE) was a large-scale, multi-platform surface wave experiment that was conducted in the southern Middle Atlantic Bight (MAB) region off the U.S. east coast during the fall and winter of 1990-1991. The purpose of the experiment was to study the dynamics and evolution of the directional wave field in response to meteorological forcing making use of recent advances in in situ data collection and data analysis, numerical wave modelling, and airborne remote sensing (Weller et al. 1991). Sponsoring agencies included the Office of Naval Research, the National Aeronautics and Space Administration (NASA), and the U.S. Army Corps of Engineers (USACE). The experiment was organized into several "Intensive Observation Periods" (IOPs). Previous USACE SWADE data reports (Caruso et al. 1993, 1994) have documented the moored buoy and other in situ data, AXBT data, and model-generated wind and current field data. A few examples of remotely sensed wave data from NASA's Surface Contour Radar and the French RESSAC instrument were included in the IOP-3 report (Caruso et al. 1994).

Of the several remote sensing instruments participating in SWADE, NASA's Radar Ocean Wave Spectrometer (ROWS) instrument was the most heavily exercised. ROWS collected approximately 45 hr of high-resolution, directional wave spectra and wind speed data on more than a dozen aircraft flights before, during, and after the last IOP (IOP-3). Funding for these flights was provided by NASA and USACE. USACE also contributed to the processing of these data with follow-on funding in fiscal year 1993. Processed data include 158 spectra files and 88 wind speed files for 12 flights conducted over the period 12 February - 7 March, 1991. A subset of these data for the "St. Valentine's Day" frontal episode (14-16 February, 1991) has been further analyzed and published as a case study (Jackson and Jensen 1995). This study demonstrated both the high quality of the ROWS data and the importance of the radar data in providing extended coverage (i.e., beyond that provided by the SWADE buoy array) in the case of large-scale wind/wave events.

This report presents all ROWS data that have been processed to date for the SWADE mission. The report also presents buoy and model data for the St. Valentine's (StV) data collection period. Appendix A contains time series of buoy environmental data (pressure, temperature, etc.) for the StV

data collection period. Appendices B and C contain analysis surface wind and current fields for the same period. Appendix D contains the buoy directional spectra for the StV period. Appendix E contains fully scaled ROWS directional spectra for both StV and IOP-3 data collection periods and log-energy and frequency-direction plots for the StV period. Interpolated values of wind speeds from the ROWS altimeter mode are presented in the directional spectra plots in Appendix E along with inferred significant wave heights. Appendix F is a collection of daily weather maps for the study period. Appendix G is a notation of symbols and abbreviations used in the report. Statistical comparisons of ROWS and buoy wind speeds are provided in Chapter 4.

2 In Situ and Model Data

In Situ Data

The buoy network in SWADE consisted of four National Data Buoy Center (NDBC) 3-m discus buoys equipped with Hippy heave-pitch-roll sensors, identified in SWADE as Discus-N(orth), Discus-E(ast), Discus-C(enter), and Buoy Coastal Engineering Research Center (CERC); four small meteorological buoys (MiniMet buoys); the operational NDBC non-directional wave-sensing buoys in the east coast NDBC network; and several C-Man stations along the coast as described by Weller et al. (1991) and Caruso et al. (1993, 1994). The locations of these in situ data collection platforms are shown in Figure 1. The inset to Figure 1 shows the configuration of the three NDBC "SWADE buoys," viz., Discus-E, -N, and -C. These buoys were equipped with a K-Gill rapid response anemometer, the standard propeller/vane anemometer, air and water temperature sensors, and humidity and pressure sensors, as indicated in the inset. The buoy positions shown in Figure 1 are the same as at the time of deployment, except for Discus-E, which was captured by the Gulf Stream on January 24, 1991, and deposited 40 km northeast of its original position. Of the four original MiniMets, only MET-3 remained on station throughout SWADE, the others having drifted out of the area (Caruso et al. 1994).

Data from these buoys and C-Man stations have been archived at the NASA/Wallops Flight Facility (WFF) SWADE Data Archive Center (Oberholtzer and Donelan 1996) and are accessible by file transfer protocol with anonymous log on. Directional wave data from the NDBC discus buoys have been processed by the classical harmonic analysis technique (Longuet-Higgins, Cartwright, and Smith 1963), by NDBC (Steele, Teng, and Wang 1992), and by the maximum likelihood method (MLM) as described by Drennan, Graber, and Donelan (1996). In processing the heave, pitch, and roll co- and cross-spectral data for the directional distribution by MLM, the inversion occasionally fails for a particular frequency, or even for a band average. In this case, the processing reverts to the classical harmonic analysis method. The buoy spectra in this report have been produced by MLM.

Time series of in situ environmental data (temperature, pressure, etc.) for nine SWADE platforms during the StV observational period are

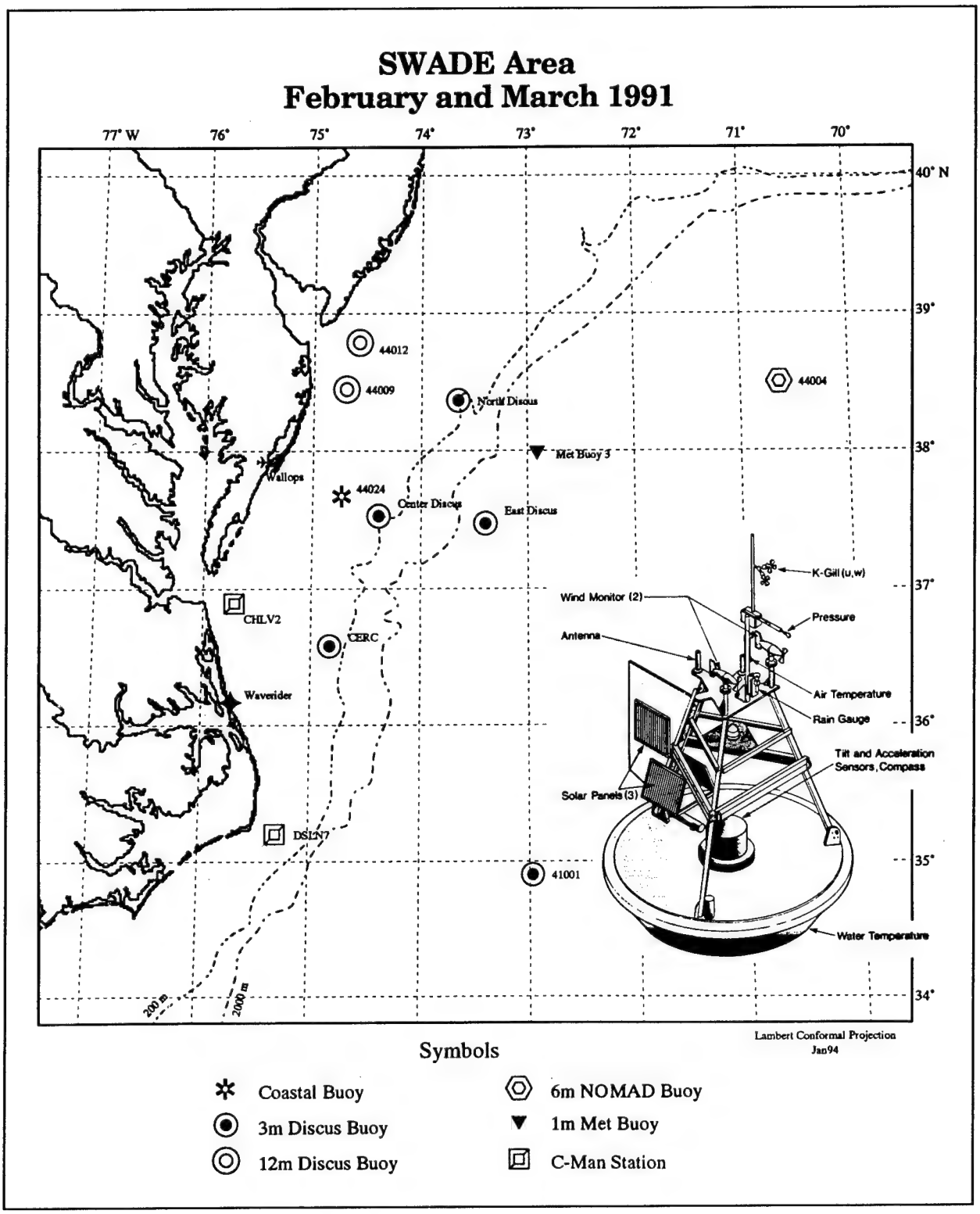

Figure 1. Locations and types of in situ data collection platforms in the southern middle Atlantic Bight region during the latter part of the SWADE experiment. The insert shows an NDBC 3-m discus directional wave sensing buoy as modified for SWADE (from Weller et al. (1991))

presented in Appendix A. Table 1 lists these platforms. Wind speeds in these plots are the raw anemometer-level wind speeds. In situ wind speeds have also been converted to neutral equivalent 10-m-level wind speeds U_{10n}[1] using two boundary layer models, the Cardone (1969) model, and the Large and Pond (1981) model. Average neutral wind speeds (and wind directions) for the SWADE area during the StV period are shown in Figure 2. In this figure, the St. Valentine's Day wind/wave event can be seen in the ~ 90-deg turning of the wind from southerly to westerly following the passage of a cold front on February 14.

Buoy directional spectra for the StV period 12-16 February are presented in Appendix D. Buoy spectra for the IOP-3 period (25 February - 9 March, 1991) are documented in the report by Caruso et al. (1994).

Table 1
In Situ Data Collection Platforms

Platform	Buoy No.	Latitude	Longtitude	Type of Spectra	Note
Discus-N	44001	38°22'N	73°39'W	Direct. spectra	1,2
CERC buoy	44014	36°35'N	74°50'W	Direct. spectra	1,2
Discus-E	44015	37°29'N	73°24'W	Direct. spectra	1,2
Discus-C	44023	37°32'N	74°23'W	Direct. spectra	1,2
EXP buoy	44024	37°41'N	74°43'W	Nondir. spectra	1,2
MET-3	44020	38°00'N	72°55'W	No spectra	2
NDBC buoy	44004	38°30'N	70°39'W	Nondir. spectra	1,2
NDBC buoy	44012	38°47'N	74°35'W	Nondir. spectra	1,2
C-Man Sta.	CHLV2	36°54'N	75°42'W	Nondir. spectra	1
C-Man Sta.	DSLN7	35°12'N	75°18'W	Nondir. spectra	1,2

[1] Data used for SWADE area winds in Figure 2.
[2] Data used for altimeter wind speed comparisons.

Model Data

Coarse-gridded National Meteorological Center (NMC) wind fields have been interpolated and regridded on a high-resolution 0.3-deg latitude by 0.5-deg longitude regional-domain grid using an objective interpolation

[1] For convenience, symbols and abbreviations are listed in the notation (Appendix G).

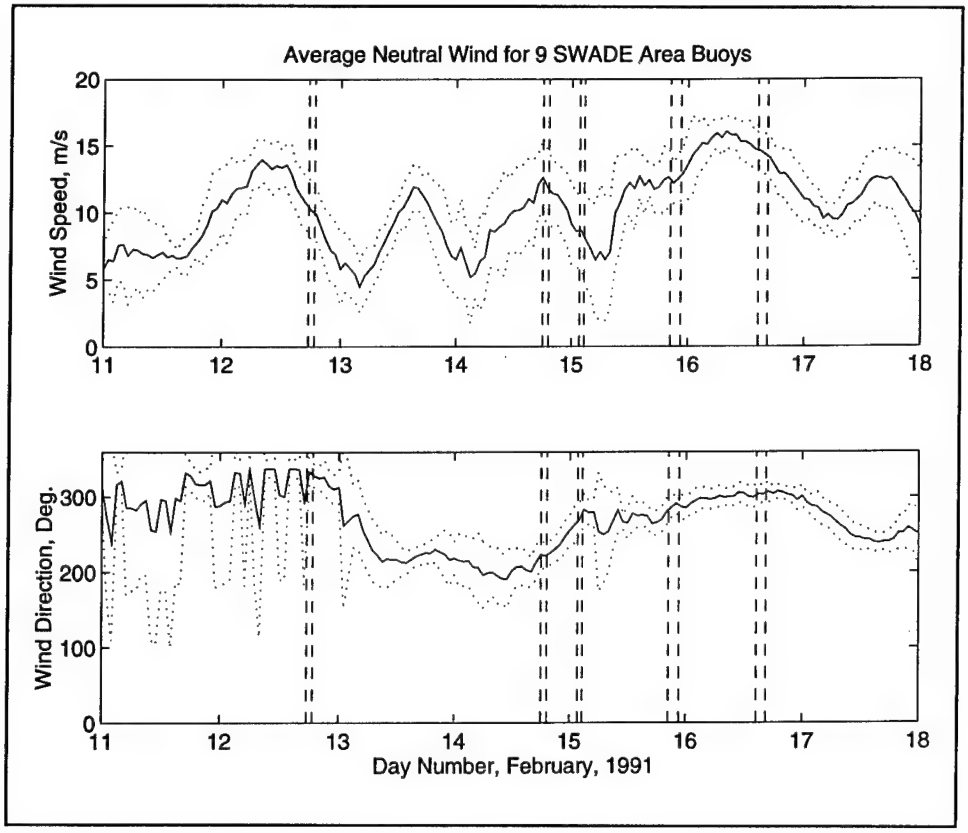

Figure 2. Average 10-m neutral wind speed (upper panel) and average wind direction (lower panel) with standard deviations (dotted curves) for the nine platforms listed in Table 1 during the St. Valentine's data collection period. The vertical dashed lines define the radar flight times. The boundary layer model used is the Large and Pond (1981) model

scheme (a conditional relaxation method) incorporating SWADE buoy data and, with lower weighting, ship reports (Gemmill 1991). In the course of the analysis procedure, the lowest-level NMC winds are reduced to surface, 10-m-level winds via a boundary-layer model. The NMC surface wind fields are shown in Appendix B for the StV period.

The current fields reported here are from the U.S. Navy Operational Gulf Stream Forecast System (NOGUFS). NOGUFS routinely provides analyses and forecasts of the current field using an eddy-resolving model incorporating optimally interpolated drifting buoy data and satellite thermal infrared sea-surface temperature and radar altimeter sea-surface topography data (Fox, Carnes, and Mitchell 1991). These surface current fields for 14-16 February are shown in Appendix C.

3 ROWS Data

ROWS Technique

The NASA/Goddard Space Flight Center's Radar Ocean Wave Spectrometer (ROWS) is a 14-GHz pulse compression radar that was initially developed as an aircraft test bed instrument for a potential satellite wave measurement system (Jackson, Walton, and Baker 1985; Jackson, Walton, and Peng 1985; Jackson 1987; Jackson 1991). Until recently, when automatic mode switching was implemented (cf. Vandemark et al. 1994a,b), the radar would have to be manually cycled between its two measurement modes: a 'spectrometer' mode and an 'altimeter' mode. Each instrument mode employs a different antenna to accomplish a specific measurement task.

In the spectrometer ('S') mode (Figure 3), a small rotary antenna whose optical axis is inclined to 16 deg from the vertical is used to measure the two-dimensional, directional reflectivity spectrum of the sea surface. At small incidence angles, the surface radar reflectivity variations are mainly due to geometrical tilting of small-scale, specularly reflecting wave facets by the underlying dominant waves. For wind speeds in excess of several meters per second, the slope variance of the smaller scale waves is generally large compared to the slope variance of the dominant waves. In this case the reflectivity modulation process can be assumed to be approximately linear on the slopes of the dominant, energy-containing waves. At high aircraft altitudes, the antenna's two-dimensional footprint on the surface is generally large compared to the scale of the dominant waves. (This is the feature of ROWS that makes it directionally sensitive). In the limiting case of large footprints, it can be shown that the wave number spectrum of the surface reflectivity modulation as seen by the radar for any particular azimuth ø of the antenna is directly proportional to the directional wave slope spectrum as

$$P_m(k,\phi) = \alpha\, k^2\, F(k,\phi) \qquad (1)$$

where

k = (radian) wave number

α = measurement sensitivity coefficient

F = directional wave-height variance, or energy, spectrum

At microwave frequencies, the reflecting wave slope elements are approximately normally and isotropically distributed (Jackson et al. 1992). The sensitivity coefficient can then be expressed simply in terms of a single scalar surface parameter, the diffraction-effective mean square slope (*MSS*), as

$$\alpha = \left(\sqrt{2\pi} / L_y\right) \left(\cot\theta_e + 2\tan\theta_e / MSS\right)^2 \tag{2}$$

where

L_y = lateral, 1-sigma, antenna footprint dimension

θ_e = effective incidence angle

This angle is usually taken to be 13 deg, which is the nominal incidence angle for the maximum power return within the radar range, or elevation angle, data window. The isotropy assumption is generally good to within ± 10 percent or so in terms of the inferred directional spectrum of the energy-containing waves. However, anisotropy of the small-scale slope elements can be accounted for by using the *MSS* in Equation 2,

$$1/MSS \rightarrow 0.5\left[\cos^2(\phi - \phi_1)/MSS_1 + \sin^2(\phi - \phi_1)/MSS_2\right] \tag{3}$$

where the one- and two-subscripted *MSS*s are the principal mean square slope components, and where ϕ_1 is the major axis direction. The slope anisotropy aspect ratio, $R = MSS_2/MSS_1$, may range from a low of $R \approx 0.8$ in strongly wind-driven cases to the isotropic limit of $R = 1$ in cases of low and variable winds (Jackson et al. 1992). The major axis direction generally lies close to the local wind direction.

Assuming the linear, deep-water, gravity-wave dispersion relationship, viz., $f = (gK/2\pi)^{1/2}$

where

f = frequency in hertz

K = wave number in cycles per meter

g = acceleration of gravity

Equation 1 can be rewritten for the directional height, or energy spectrum, in the frequency domain,

$$E(f,\phi) = (\pi\alpha f)^{-1} P_m(K,\phi) \quad (4)$$

The energy spectrum E is defined so that the significant wave height SWH,

$$SWH \equiv 4\, E_o^{1/2} \quad (5)$$

where the wave height variance $E_o = \iint E(f,\phi) df d\phi$. Normally, ROWS is operated at altitudes between 5 km and 10 km. The half-power antenna footprint dimensions are then of the order of 350-700 m in azimuth and 750-1,500 m in surface range. The combination of the finite sample window in surface range and azimuth and the finite azimuth swept out during the system integration time results in directional and wave number resolutions, respectively, on the order of 30 deg or better and 20 percent or better for waves shorter than 200 m. Statistical stability requires the averaging of spectra from a number of antenna rotations. Usually 10 rotations are averaged. When the spectra are symmetrized by averaging the spectral estimates 180 deg apart in azimuth, the resulting directional spectrum estimates have 40 degrees of freedom per elementary wave number and direction band.

Ideally, the *MSS* components and sensitivity coefficient α would be computed from the average power received in the spectrometer mode. However, because of the steep incidence angle (16 deg) and the relatively narrow elevation beam width (10 deg) of the antenna, the spectrometer mode power return is quite sensitive to aircraft altitude and antenna pointing errors, and so reliable estimates of the *MSS* and sensitivity coefficient are not easily obtainable in this system mode. This is one reason why the system is switched intermittently to the altimeter ('A') mode (Figure 3). This mode uses a relatively broad-beam antenna; hence the return power is relatively insensitive to aircraft altitude and antenna alignment errors. Estimation of the *MSS* parameter and the surface wind speed from the ROWS altimeter mode data is discussed in Chapter 4.

SWADE Mission

In SWADE, ROWS was operated on a small, twin-engine, T-39 training jet (Figure 4). The aircraft has a maximum altitude of about 12 km and a range of about 3 hr (about 2,200 km). Most of the SWADE flights reported here were at a constant standard pressure altitude of 7,625 m. The aircraft is less stable than the larger platforms used previously, and aircraft pitch, roll, and yaw motions affect the data reported here to an extent that has not been well determined. One effect of the aircraft motions is to cause an error in the assumed azimuth of the antenna pointing of the order of *yaw angle + (antenna rotation axis tilt) X cot* θ_e where θ_e is the nominal incidence angle. To the first order, this will not affect the measurement of mean wave directions from the symmetrized spectra, but it will

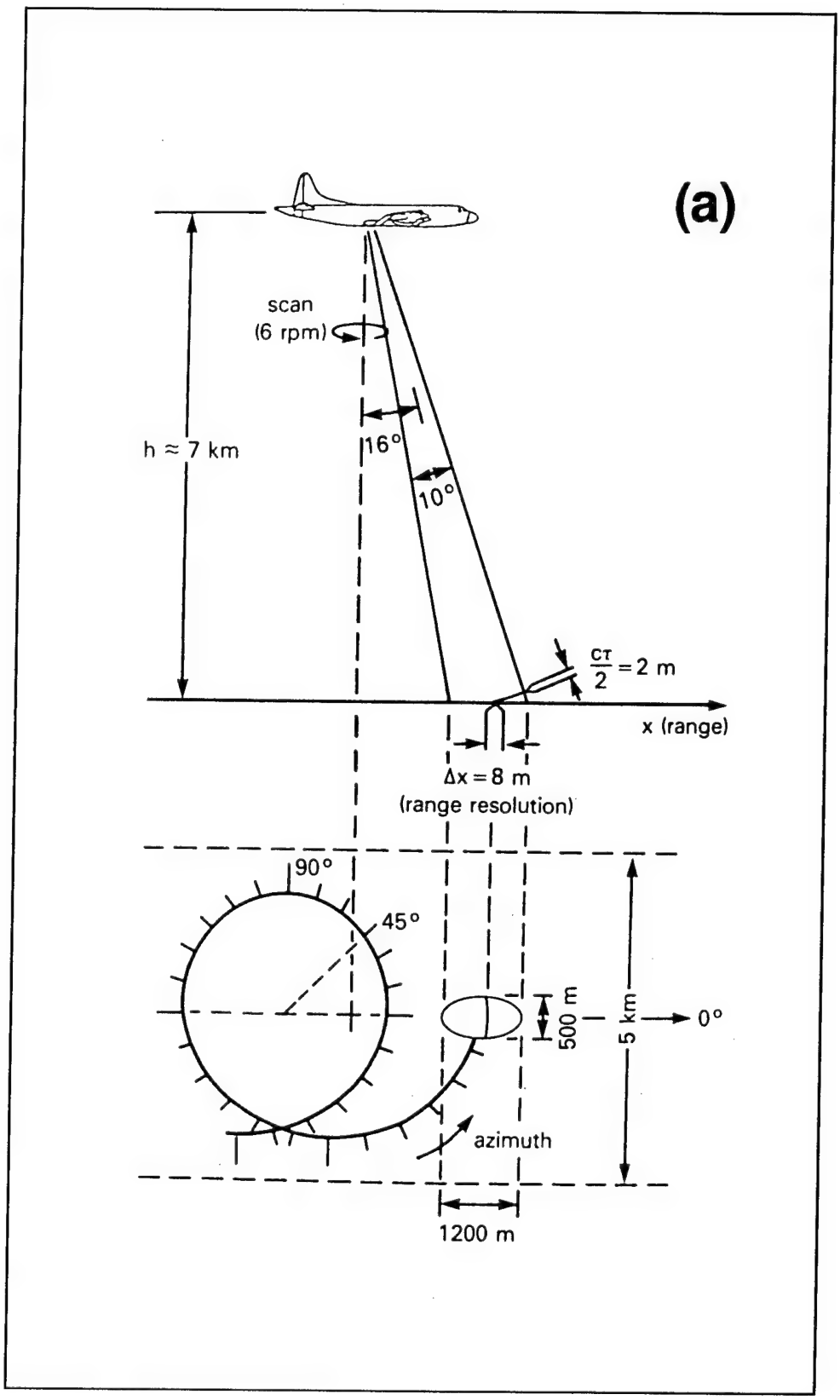

Figure 3. Radar Ocean Wave Spectrometer (ROWS) measurement geometry, (a) spectrometer ('S') mode (Continued)

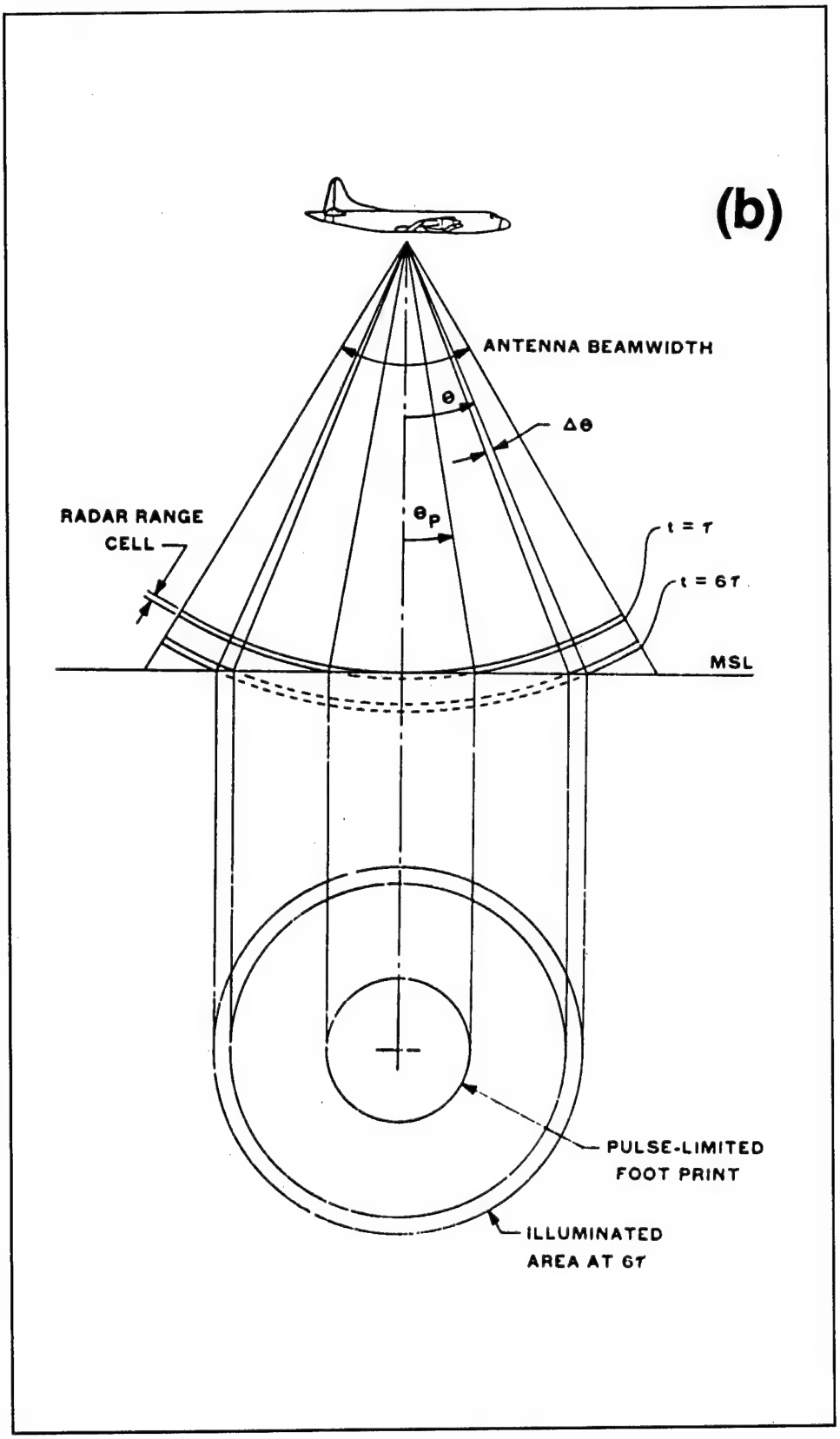

Figure 3. (b) altimeter ('A') mode (Concluded)

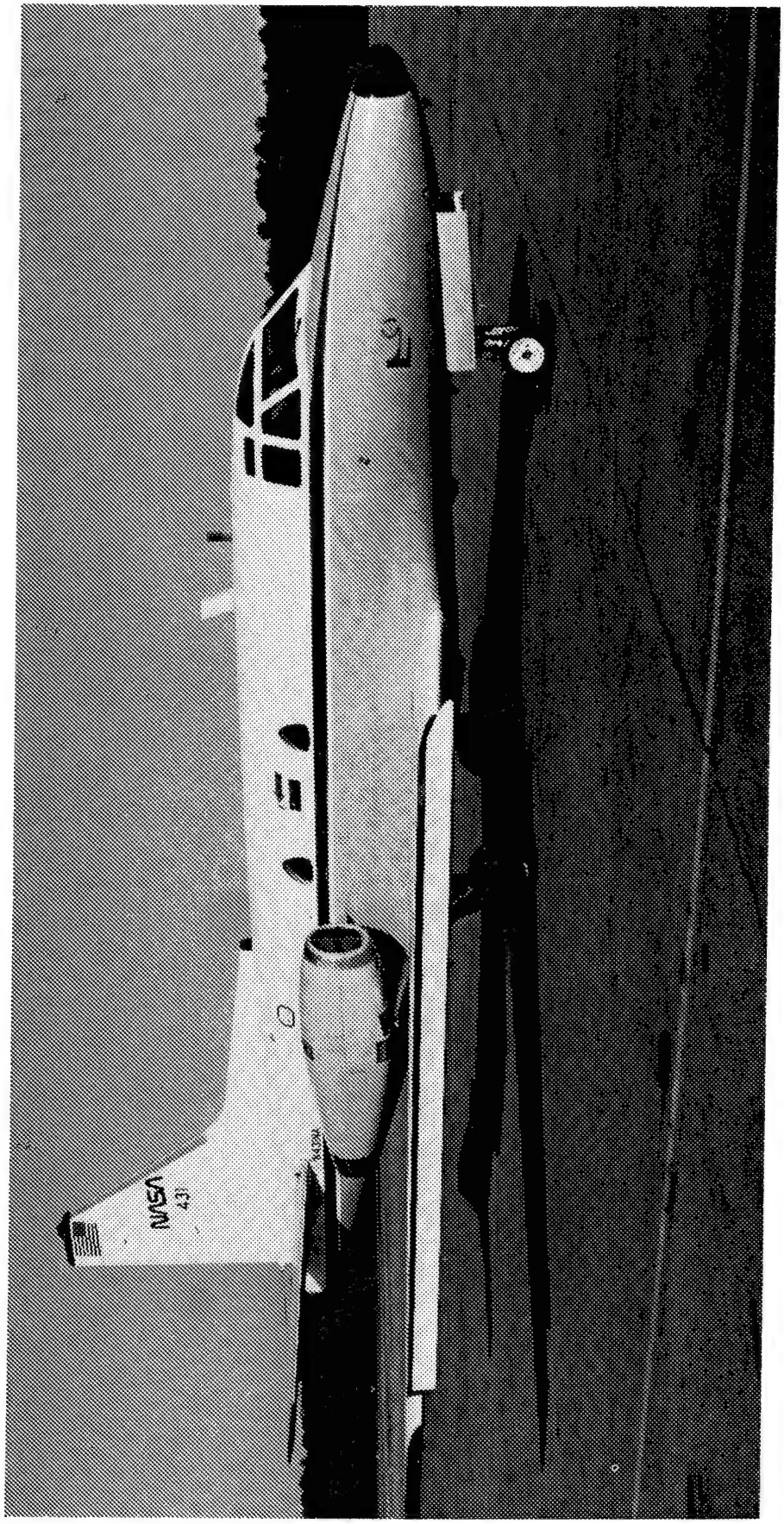

Figure 4. NASA's Wallops Flight Facility T-39 aircraft

broaden the apparent directional spreading beyond that associated with the finite directional resolution of the system.

For SWADE, ROWS was configured with a new PC-based data acquisition system that could store up to 2.5 hr of 10-ns-sampled, 100-Hz pulse-return data on a single video cassette tape (Exabyte recording system; cf. Ward 1992). Recording resolution was eight bits and the frame size was 1,024 bytes. The pulse return data occupy the first 700 bytes of the frame; the remainder of the frame is reserved for housekeeping data. Unfortunately, it was not possible to implement automatic navigation data logging-in time for the experiment. Hence, all navigation data had to be hand-logged and flight lines and file locations manually reconstructed post-flight from the radar log, pilot's flight plan, and other sources.

In all, 17 ROWS/T-39 data flights were made between 22 January and 25 March, 1991. The dates and times of these flights are given in Table 2. Selected data from 13 of these flights have been processed; but, because adequate scaling data for the 11 February flight are lacking, data from only 12 flights are presented here. These include data from five flights in the StV period (12-16 February) and from seven flights in the IOP-3 period (27 February - 7 March). Only a small fraction of the total amount of data recorded could be processed owing to time and funding limitations. The data presented herein represent a survey of the data for each flight consisting of some 10-20 S-mode files and 5-10 A-mode files per flight. The S-mode data were processed as 100- or 150-s subfiles of the original data files, which are typically 3-5 min in length. The 100-s record lengths can correspond to anywhere between 15 km and 30 km of flight track, depending on the aircraft ground speed. The A-mode data, as a rule, were processed in 10-s subfiles. These files were generally recorded alternately with the S-mode data so as to provide scaling coefficients for the S-mode data as discussed in Chapter 4. The reconstructed flight lines accompanying the ROWS spectra in Appendix E are simplified versions of actual ground tracks which are meant only to establish the overall flight pattern. Thus, turning maneuvers, special flight patterns over buoys, and reverse courses are not shown on these maps.

SWADE Data Processing

Data processing consisted of three stages, as shown in Figure 5.

a. Preprocessing. The QUICKBASIC program PREROWS2 (Vaughn 1993) is used to (1) generate tapescans (Exabyte logs) of the flight data tapes, (2) determine the 0 deg antenna shaft encoder bit change record location, and (3) assure data quality. The Exabyte logs are used together with radar logs of navigation and file data to generate a list of files with starting frame locations for processing (N*.ASC files, * = date). The selected S-mode and A-mode data sequences (or subfiles) are then read by

Table 2
ROWS Flight Summary

Date (1991)	Hours (LST) (UT - 5)	No. Spectra Processed	Remarks
Jan 22	14:20-16:10	None	Poor ancillary data
Feb 11	15:45-17:30	5	Unscaled spectra
Feb 12	12:05-14:00	11	
Feb 14 #1	12:20-14:31	15	Start St. Valentine's
Feb 14 #2	20:10-22:00	11	
Feb 15	15:12-17:53	19	
Feb 16	09:10-11:55	22	End St. Valentine's
Feb 27	18:15-20:30	9	Start IOP-3 flights
Feb 28	14:15-17:27	18	
Mar 02	15:27-18:30	10	
Mar 04	16:10-18:45	18	
Mar 05	11:43-14:14	11	SWADE priority day
Mar 06	14:02-15:38	7	
Mar 07 #1	16:40-19:40	11	
Mar 07 #2	22:00-00:20	None	End IOP-3 flights
Mar 11	17:25-18:57	None	
Mar 25	10:50-12:30	None	

PREROWS2 and transferred to hard disk and stored as 10-MB (S-mode) and 1-MB (A-mode) files.

b. Processing. The selected data files on hard disk are input to the C programs SAXALTD (A-mode data) and SAXSPEC (S-mode data), the original versions of which were developed for SAXON-FPN data (Jackson et al. 1993). The output of SAXSPEC (Version 2.1) consists of ASCII hard disk files (*.SRF files) of peak-value scaled directional modulation spectra P_m and ancillary data listings of the processing statistics (*.LST files). These files, along with the A-mode output files (*.OUT files), have resided at the WFF SWADE Data Archive Center since early 1993 in flight day directories (where the file tags * = local times).

Some routines in SAXSPEC differ from the routines described in Jackson, Walton, and Baker (1985) and Jackson, Walton, and Peng (1985).

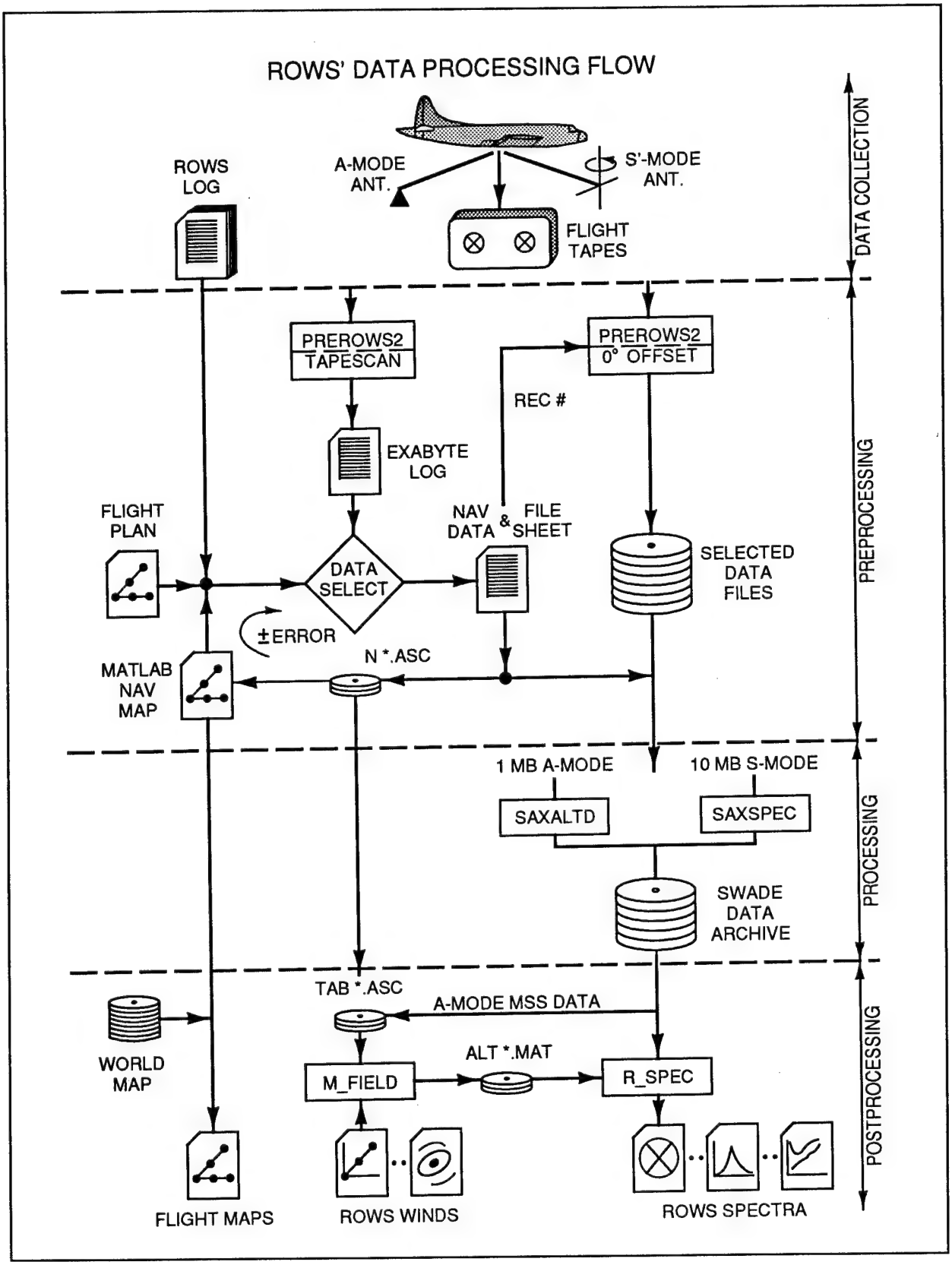

Figure 5. ROWS data processing flow

(1) Range data window: Inner and outer incidence angle limits are 7 deg and 20 deg, but the window may be smaller if the 10 percent of peak power points lie interior to this interval.

(2) Delay time to surface range transformation: The 10-ns time bins are rebinned into 8-m surface range bins using a 16-m boxcar smoother.

(3) Azimuth sectors: An 18-deg sector is chosen for the basic pulse integration (50 pulse average). The spectra for these sectors are then interpolated and output in 12-deg azimuth bins in a true north-oriented reference frame.

(4) Average power estimation and normalization: The average power envelope estimate for any sector is given by a model function fit based on a skewed normal quasi-specular scattering cross section. Four parameters are derived from the average power envelope fit using a third degree polynomial approximation to the logarithm of the return power for each sector. While the fit is generally excellent, there is some low-frequency content that is not accounted for, and so some of these data (particularly for low sea states) may have a fair amount of 'dc' component. From the cubic fit parameters we may recover pitch and roll and surface slope distribution skewness (the last only if external altitude data are available), surface mean square slope, and principal axis direction. The fit parameters are listed in the last four columns of the sector summary data in the *.LST files. After power normalization, the usual Hanning window is applied to the wave modulation signal.

(5) Noise background subtraction: The average value of the spectrum in the last 32 bins is used as a preliminary estimate of the noise background.

The surface range window for FFT is 2,048 m. When this exceeds the actual range extent of the pulse return data, the record outside of the actual data window (e.g., as determined by the 7-deg and 20-deg points) is padded with zeros. Accordingly, the spectral resolution will generally be less than that indicated by the elementary wave number bin size and there will be some correlation overlap between spectral estimates. For data compression, the spectrum data are block averaged in logarithmically spaced intervals to produce 35 output bins. In the frequency domain, the rebinned data range from $f = 0.055$ Hz to $f = 0.31$ Hz.

c. Postprocessing. All successfully executed A- and S-mode output files for each flight are ordered sequentially as Smmdd.nn and Ammdd.nn files, where mmdd = month and day and nn = file sequence number. The header data for the *.SRF files are stripped and the peak normalization constant is inserted into the (1,1) matrix element of the 36 X 31 arrays (row 1 = azimuth in degrees, column 1 = frequency in Hz). The navigation and file tables N*.ASC (* = mmdd) are augmented with A-mode altitude and *MSS* data and stored as TAB*.ASC files.

All postprocessing software is written in MATLAB for PC:

(1) The program M_FIELD reads TAB*.ASC data and interpolates A-mode *MSS* and U_{10n} data to the S-mode file locations as described in Chapter 4. The output data for each flight are stored as ALF*.MAT files (* = mmdd). Table 3 describes these data files.

Table 3
ALF*.MAT File Contents

Column	Data Element
1	File sequence number
2	Month
3	Day
4	Hours, UT
5	Minutes
6	Latitude, degrees north
7	Longitude, minus degrees west
8	Aircraft altitude, m
9	Aircraft ground speed, m/s
10	Aircraft heading, degrees true
11	Neutral 10-m wind speed U_{10n}, m/s
12	Mean square slope (*MSS*) parameter
13	Minimum degrees of freedom

(2) The program R_SPEC reads the S*.nn (* = mmdd) header-stripped spectral matrices and scales the spectra using the interpolated *MSS* data in ALF*.MAT. A correction factor, FAC = 4*delx*256 (delx = 8 m) is applied to the spectra to correct a scaling error in SAXSPEC. The routine SENS is then called on to compute the sensitivity coefficient _ from the *MSS* data according to Equations 1-3. For all data except the StV data, an isotropic *MSS* is used; for the StV data, the anisotropic form (Equation 3) is used. In SENS the measured *MSS* is subject to a correction based on the difference between the *MSS* versus wind speed relationship in the original ROWS training data set for wave spectra (Jackson, Walton, and Baker 1985) and the altimeter wind speed versus *MSS* relationships (Equation 10). The correction is

$$MSS_{\alpha} = 1.22\, MSS_{Measured} - 0.007 \qquad (6)$$

R_SPEC performs several other postprocessing functions as well, including a final noise background subtraction and a point target response correction. The noise background is approximated by a smoothed estimate of the minimum in the measured directional power spectrum as a function of frequency. The point target response is taken to be the same as in Jackson, Walton, and Baker (1985) and Jackson, Walton, and Peng (1985). Most of the data processed in this manner exhibit f^4 power-law behavior in the rear-face region of the wind-sea spectrum out to 0.2 Hz or more (ca. 40-m wavelength), whereafter a spectral roll-off occurs (cf. Figure 12, panel 'd'). To account for this roll-off, the observed nondirectional spectrum for $f > 0.2$ Hz is replaced by a f^4 power-law spectrum with a spectral constant that is determined by the value of the observed spectrum at 0.2 Hz.

R_SPEC generates polar contour and scaled nondirectional spectra plots by calling on the routine S_PLOT, a modified version of the plotting software used for buoy spectra. R_SPEC also contains a directional analysis package that computes the mean direction and directional spreading as a function of frequency (see Chapter 5). R_SPEC outputs the array DEL*.MAT (or the array EPS*.MAT for the anisotropic StV data) containing derived spectral products as shown in Table 4. Chapter 5 discusses these data products in more detail.

(3) The program WA_FIELD reads DEL*.MAT (or EPS*.MAT) files and plots "Custer" diagrams of the wave field and other derived data products as discussed in Chapter 5.

Table 4
DEL*.MAT and EPS*.MAT File Contents

Column(s)	Data Element
1-13	Alpha vector as described in Table 3
14	Cutoff frequency, f_min
15	Peak frequency of nondirectional spectrum, f_pknd
16	Peak period, 1/f_pknd
17	Mean period, T_bar
18	Peak of nondirectional spectrum, s_pknd
19	Confidence interval for peak, ci_pk
20	Significant wave height of tail patch region, Hs_tail
21	Significant wave height, Hs (SWH)
22	Direction at peak of directional spectrum, phi_pk
23	Peak direction at f_pknd, phi_pknd
24	Mean direction, phi_bar, according to WAM Group definition
25	Spread parameter, sig_phi, according to WAM Group definition
26-35	Blanks (NaNs)
36-70	Frequency, f
71-105	Fully scaled nondirectional spectrum, s_nd
106-140	Mean direction versus f from 2nd harmonic phase, dirs(:,4)
141-175	Half power full-width directional spread from s2 parm dirs(:,5)

4 ROWS Winds

ROWS was switched periodically from the instrument's spectrometer ('S') mode to the instrument's nadir-looking altimeter ('A') mode to collect data on:

a. Significant wave height (SWH) and wind speed (U_{10n}).

b. Mean square slope (*MSS*) for scaling the ROWS spectra.

c. Mean altitude (H) to correct the aircraft pressure altitude.

The A-mode data takes were generally around 1 min in duration as compared to 3-5 min for typical S-mode data takes. As a rule, the data takes for the two modes were alternated, or interleaved (see flight line maps in Appendix E). A problem with the triggering of the digitizer has precluded the recovery of meaningful SWH estimates from the wave form data in the leading edge region. Thus, wave height data for SWADE are only available via the scaled ROWS spectra.

A total of 88 selected A-mode files have been prepared for the 12 processed SWADE flights listed in Table 2. The locations of these files are shown on the flight line maps in Appendix E by 'X's' and the files are denoted 'A1', 'A2', etc. in the chronological order of the data takes. As a rule, the A-mode data were processed as 10-s subfiles, one subfile per file of raw data, using a four-parameter wave form fit to the average pulse return data as described below.

Wave Form Fits

As shown in Figure 3, the altimeter mode uses a relatively broad beamwidth (32.4 deg) fixed, nadir-pointing antenna to collect surface information beneath the aircraft. The antenna pattern in the main lobe is approximately Gaussian. The ROWS pulse shape is also approximately Gaussian. Since the sea surface slope distribution is quasi-isotropic and approximately normally distributed, it follows from the quasi-specular scattering model that the average altimeter power return wave form $W(t)$ is given by (Jackson et al. 1992):

$$W(t) = (A/2) \quad \left\{1 + erf\left[(t - t_o)/2^{1/2}\,\sigma\right]\right\} \quad \exp\left[-(t - t_o)/\tau\right] \tag{7}$$

where A is the wave form amplitude, t_o is the time of return from the mean sea surface (epoch), and σ and τ are the leading and trailing edge wave form parameters, respectively, given by

$$\sigma = \left[(SWH/2c)^2 + \sigma_p^2\right]^{1/2} \tag{8a}$$

$$\tau = (H/c)\left(1/MSS + 1/\sigma_b^2\right)^{-1} \tag{8b}$$

where c is the speed of light, H is the aircraft altitude, and σ_p and σ_b are respectively the 1-sigma radar pulse width and antenna beam width parameters as given in Jackson et al. (1992).

Processing of A-mode data consists of: (a) bias estimation and subtraction, (b) epoch (t_o) estimation and pulse realignment based on 50-pulse (0.5-s) averages, and (c) four-parameter iterative least square fitting of the model wave form (Equation 7) to 2.5-s averages of the realigned pulse returns, where the fit is limited to nadir angles ≤ 15 deg. The output of SAXALTD consists of four estimates each of the *MSS*, the epoch t_o (or mean altitude H), and the SWH for every processed 10-s subfile. Output also includes wind speed estimates, which are derived from the *MSS* estimates according to the algorithm described below. If no inordinate fluctuation in any of the fit parameters occurs, the four values of mean altitude, wind speed, and *MSS* are averaged and entered into the table TAB*.ASC (* = mmdd) as discussed in Chapter 3.

Figure 6 is an example of the altimeter average wave form data (10-s averages) from the March 2 flight. The power in the tail region is seen to be well approximated by exponential decay as predicted by the Gaussian specular point model (Equation 7). A linear log-power dependence on delay time holds for nearly 20 dB of dynamic range.

A posteriori wave form fit correction

Direct wind speed comparisons with the SWADE buoys (see below) show a significant bias in the ROWS wind speeds inferred from the SAXALTD full wave form fit *MSS* data. A study of the ROWS altimeter-mode wave form data from the recent HIRES mission (Vandemark et al. 1994b) shows that there is a bias between the *MSS* inferred from the full wave form fits and the *MSS* inferred by a fitting of the wave form trailing edge region

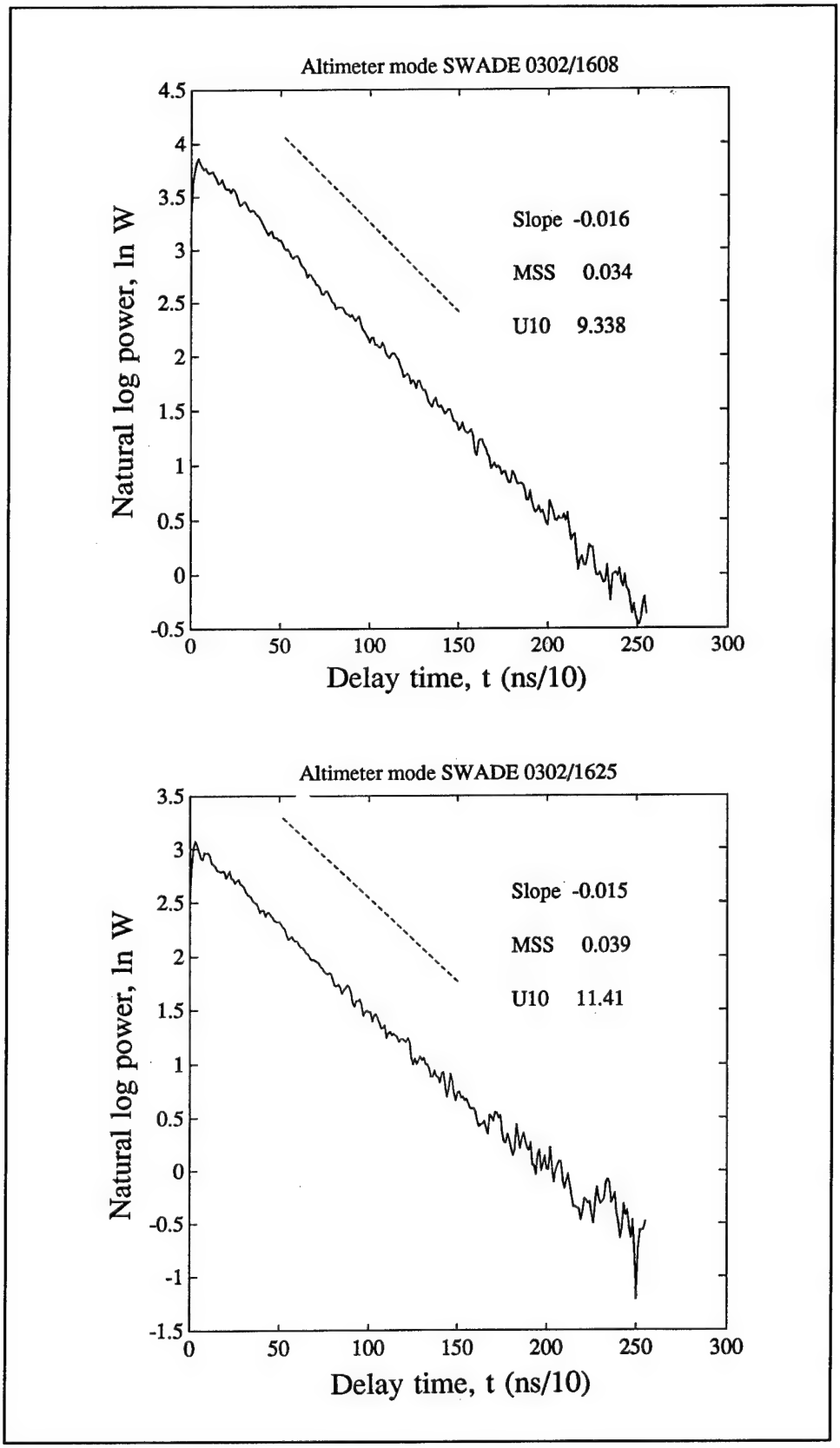

Figure 6. Examples of altimeter mode average wave form data

alone.[1] Figure 7 is a scatterplot of these data. A linear regression of *MSS* from the tail region fit on the full wave form fit *MSS* gives

$$MSS_{Tail\ Fit} = 1.0523\, MSS_{Full\ Fit} + 0.00022 \tag{9}$$

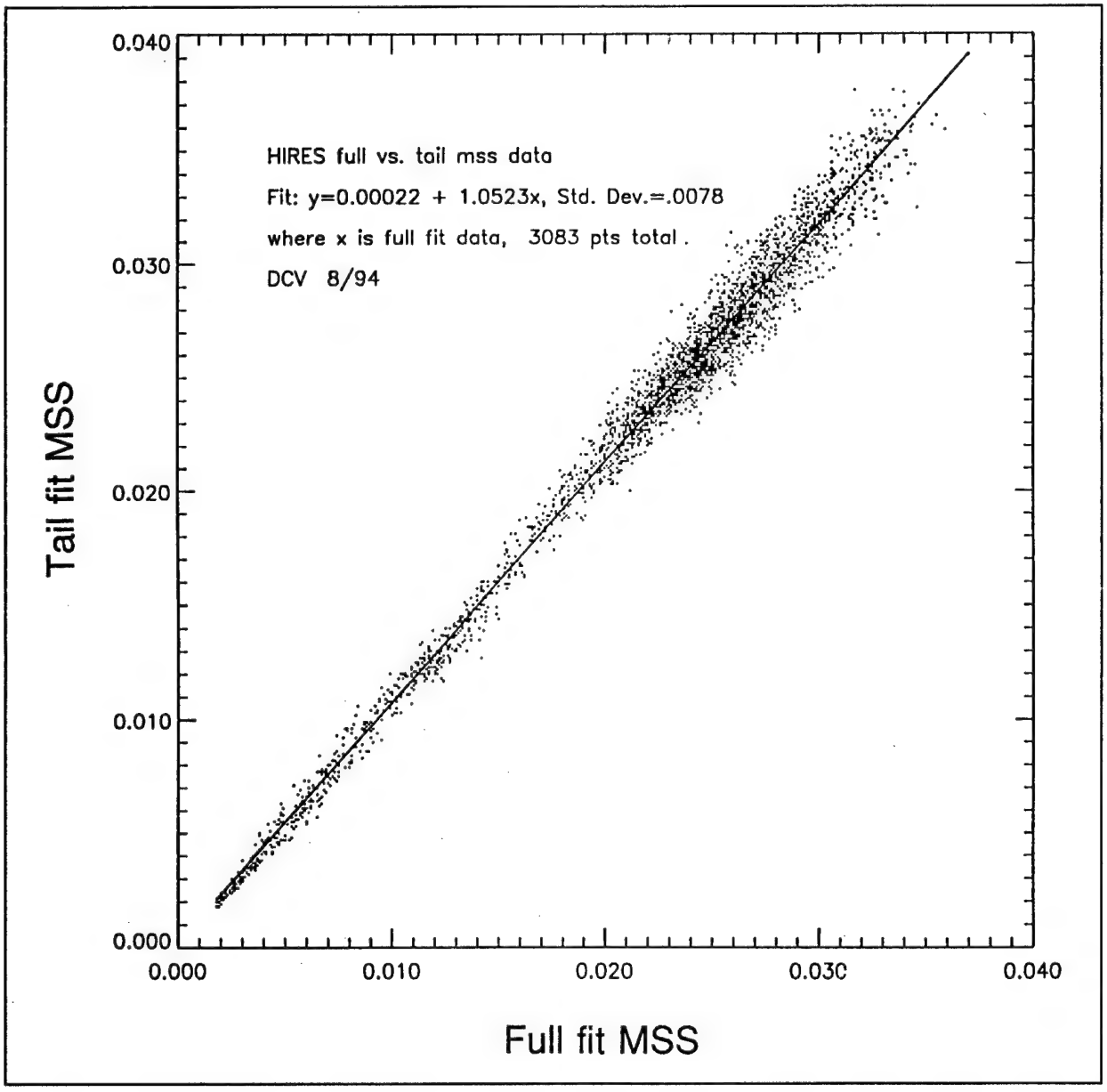

Figure 7. Scatterplot and regression analysis of full wave form fit mean square slope (*MSS*) data versus tail region wave form fit *MSS* data

[1] Personal communication, D. Vandemark, NASA, Wallops Flight Facility, Wallops Island, Virginia.

The scaled spectra and wind speed data presented in Appendix E are based on SAXALTD full wave form fit *MSS*. These stastical buoy wind speeds have been corrected according to Equation 9.

Wind speed algorithm

For wind/wave conditions not too far removed from equilibrium, the *MSS* can be expressed in terms of the 10-m-level neutral equivalent wind speed U_{10n} according to the quasi-empirical relationships found in Jackson et al. (1992). The ROWS wind speed algorithm consists of the inverse of these relationships, viz.,

$$U_{10n} = \exp(100 * MSS - 1.1), \qquad 0 \le MSS \le 0.028 \tag{10a}$$

$$U_{10n} = (MSS - 0.013)/0.0023, \qquad MSS \ge 0.028 \tag{10b}$$

Although the relationships of Equation 10 were developed from ROWS aircraft data alone, they provide excellent predictions for satellite altimeter wind speed data (Jackson et al. 1992).

Interpolation Fields

As discussed in Chapter 3, ROWS spectra in SWADE are scaled using A-mode estimates of the *MSS*. Because the A-mode data do not always neatly bracket the S-mode data, a simple linear interpolation between adjacent data points is generally not possible. Instead, two-dimensional least squares interpolating polynomials of the *MSS* and U_{10n} are constructed as functions of latitude and longitude using the A-mode data input from TAB*.ASC. The degree of the fit polynomial is taken to be the highest possible consistent with the limited number of A-mode data points. The interpolating polynomials are then evaluated at the S-mode locations (principally for the *MSS* scaling data) and at the buoy locations (principally for wind speed comparisons). The fits are accomplished using the MATLAB program M_FIELD. The interpolated *MSS* and U_{10n} data at S-mode file locations are output in the MATLAB data file ALF*.MAT.

Evaluation of the 2-D fit polynomials at the A-mode locations shows a fit error of at most 1 ms^{-1} rms in terms of wind speed. Thus we expect a fairly good representation of the local *MSS* at the S-mode file locations, except perhaps in cases of rapid wind/wave field changes (for example, near currents); or, in cases where there are only a few A-mode data points to define the field; or, in cases where the S-mode and A-mode files are geographically widely separated. Figure 8 shows the constructed fields of altimeter-mode U_{10n} for the four StV flights between 14 and 16 February. The highest degree fit polynomial is $n = 3$ (for 16 February; total of 11 data points) while the lowest is $n = 1$ (for 14 February, flight No. 2; five

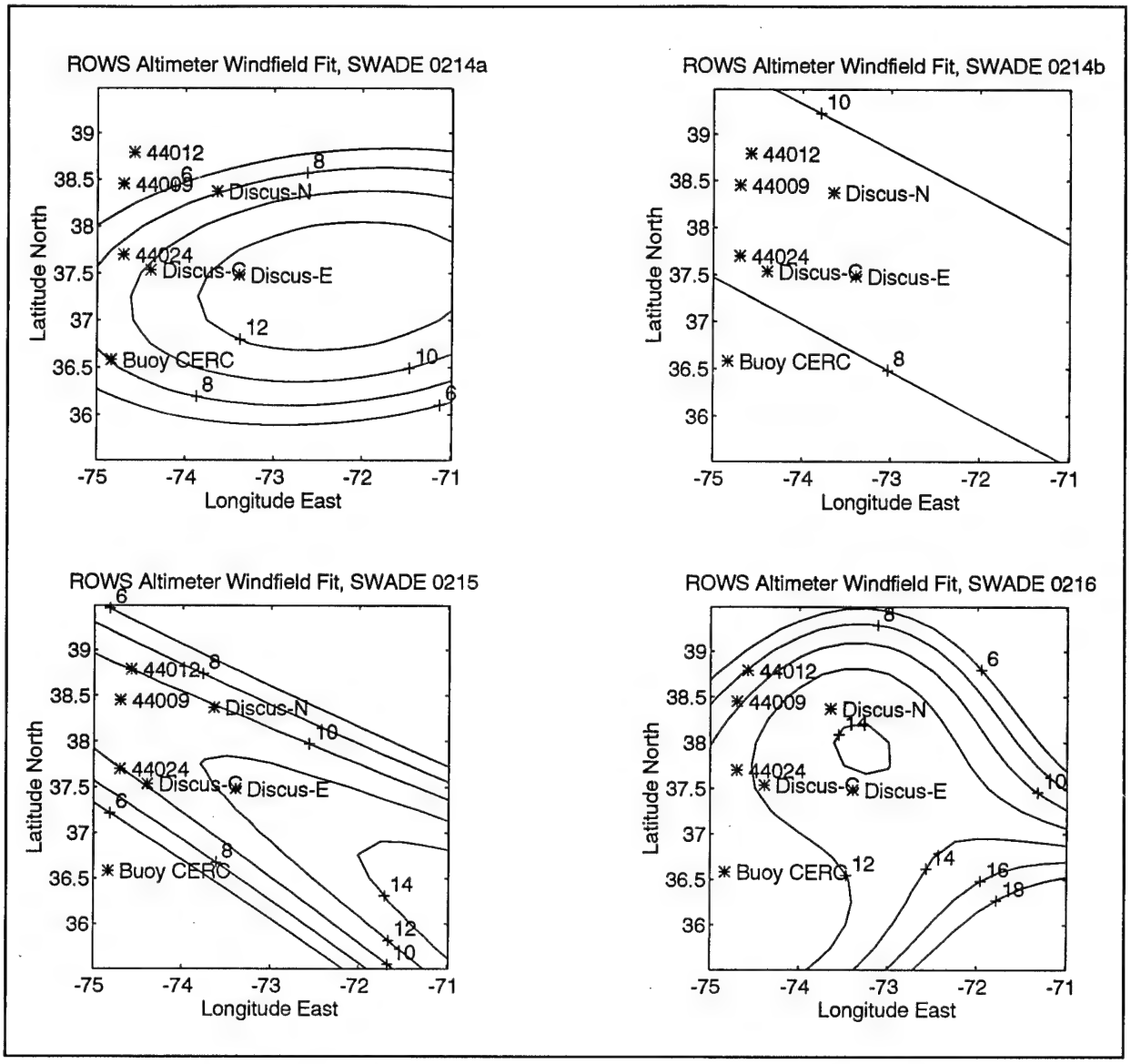

Figure 8. Fields of ROWS altimeter-mode inferred 10-m neutral wind speeds for the four St. Valentine's flights from least-square polynomial fits to the observations

valid data points). Note that in these plots, the uncorrected full wave form fit *MSS* data have been used.

ROWS Versus Buoy Winds

Indirect wind speed comparisons

Figure 9 compares the altimeter-inferred U_{10n} from the interpolation fields of Figure 8 with buoy wind speeds. The altimeter U_{10n} evaluated at

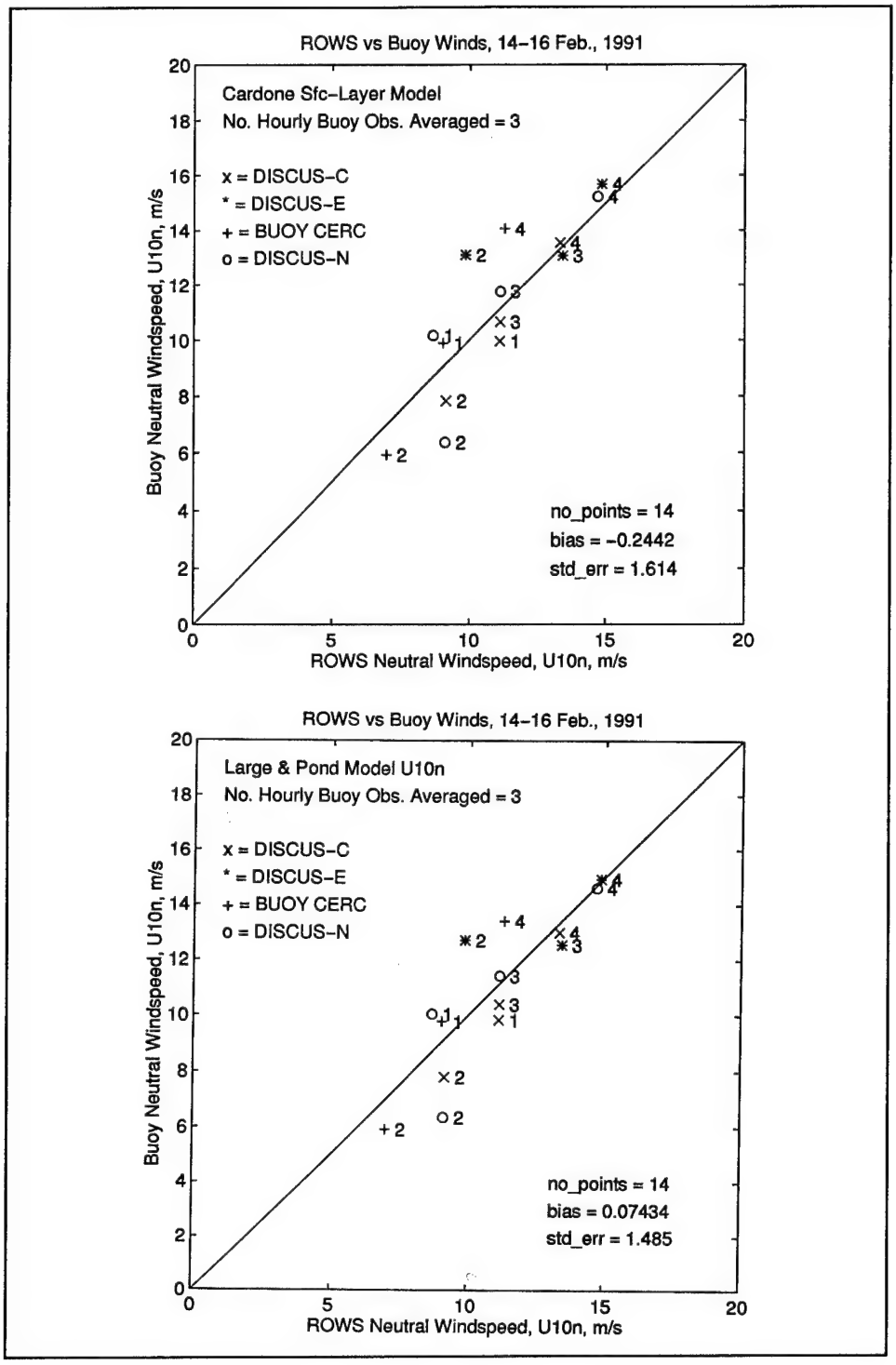

Figure 9. Buoy 10-m neutral winds versus ROWS-inferred 10-m neutral winds for the four St. Valentine's flights. The ROWS winds are from the corrected wave form fit interpolation fields corresponding to the fields of Figure 8. The buoy winds are computed using the Cardone (a) and the Large and Pond (b) boundary layer models. The numbers 1-4 indicate the ROWS flight number.

the buoy locations are compared to the mean buoy U_{10n} observed within ± 1 hr of the nominal flight time. The buoy U_{10n} are computed according to the Large and Pond (1981) boundary layer model using the buoy-measured air-sea temperature differences. The agreement is seen to be generally quite good. For StV flight No. 4 on 16 February, the flight with the highest degree polynomial fit, the agreement is better than ± 1 ms^{-1} for the three SWADE buoys, Discus-N, Discus-E, and Discus-C. For all flights there is excellent agreement with centrally located Discus-C. The data contain only one outlier, the CERC point for flight No. 2. In this case the winds were low and variable and the CERC buoy lay fairly well outside the low degree fit region of the radar flight plan. If this point (and the Discus-E null data point for flight No. 1) are excluded from the comparison, then 14 data points remain; these show a bias of + 0.8 ms^{-1} (buoy minus ROWS wind speed) and a standard error of 1.8 ms^{-1} over the observed range of ~ 7-15 ms^{-1}. We note again that the comparison here for the four flight days of the StV event is based on the uncorrected full wave form fit *MSS* data. If the wave form fit correction (Equation 9) were used, the bias might be reduced somewhat (see below).

Direct wind speed comparisons (all data)

ROWS-inferred U_{10n} for the 12 SWADE flights in the period 12 February-7 March are compared to buoy wind speeds in Figures 10 and 11. The comparisons are made for ROWS-buoy separation distances (proximity circles) of 10 km, 25 km, and 50 km. The temporal window in each case is taken to be the ROWS data take time ± 0.55 h. If two hourly buoy observations fall within this window, these observations are averaged. In all cases the in situ neutral wind speeds are computed according to the Large and Pond (1981) boundary layer model.

Figure 10 compares the full wave form fit ROWS U_{10n} estimates (as output from SAXALTD) to in situ U_{10n} estimates for the 50-km proximity circle case. The comparison consists of 49 "hits" on 9 different platforms. These platforms are listed in Table 1. The ROWS full wave form fit U_{10n} are seen to be biased low with respect to the buoy U_{10n} by about 1.5 ms^{-1}. Figure 11a shows the same comparison, but for the ROWS *MSS* data corrected according to Equation 9. With this correction, the bias in inferred U_{10n} is reduced to -0.5 ms^{-1} (ROWS - buoy). The linear regression of the in situ U_{10n} on the ROWS U_{10n} is now very close to the line of perfect agreement. Going to the smaller separation distances (Figures 11b and 11c), one sees a decrease in the standard deviation from 2 ms^{-1} in the 50-km case to 1.8 ms^{-1} in the 25-km case (22 hits) and 1 ms^{-1} in the 10-km case (7 hits). These standard deviation errors are comparable to those found in satellite altimeter versus buoy wind speed comparisons involving similar temporal and spatial offsets (Dobson, Monaldo, and Goldhirsh 1987).

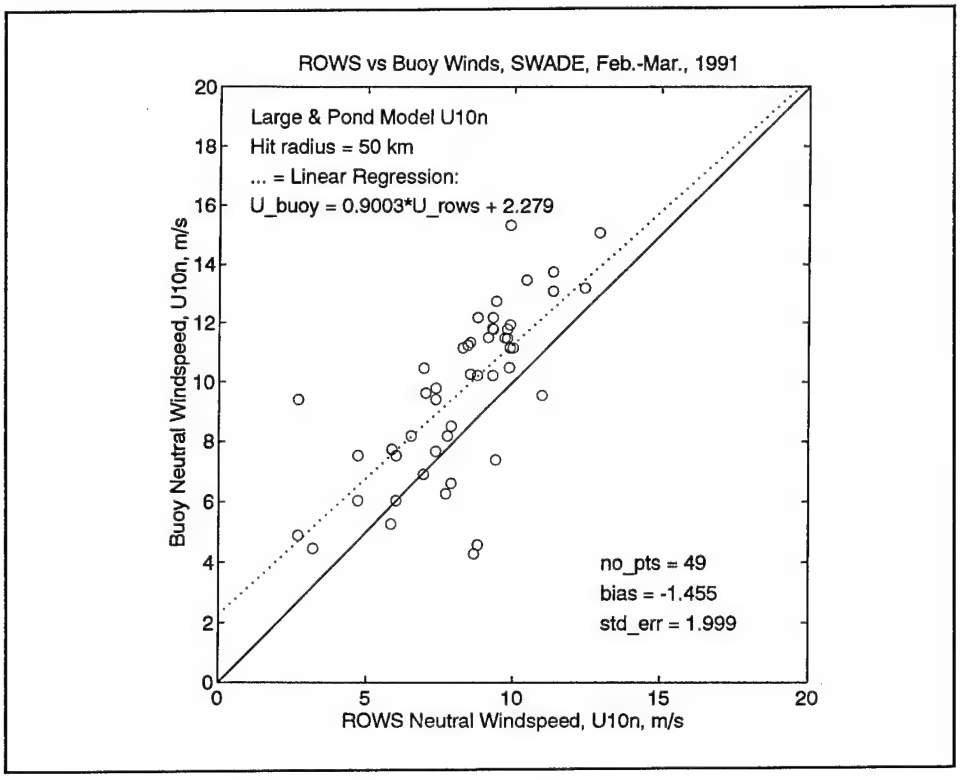

Figure 10. Buoy neutral wind speeds (Large and Pond model winds) versus ROWS uncorrected full wave form fit neutral wind speeds for a 50-km proximity circle

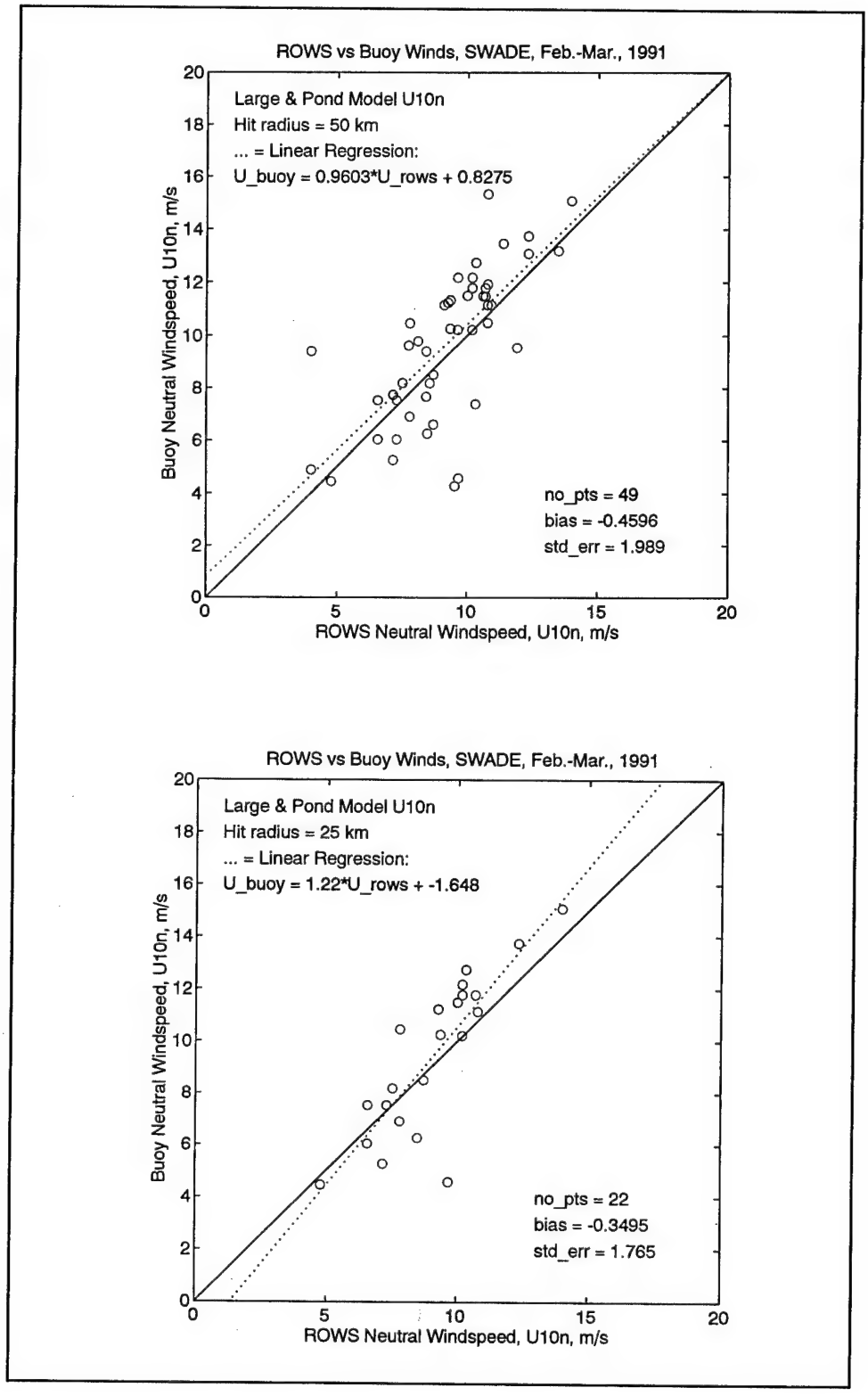

Figure 11. Buoy neutral wind speeds (Large and Pond model winds) versus ROWS wind speeds from corrected wave form fit data: (a) 50-km proximity circle, (b) 25-km proximity circle (Continued)

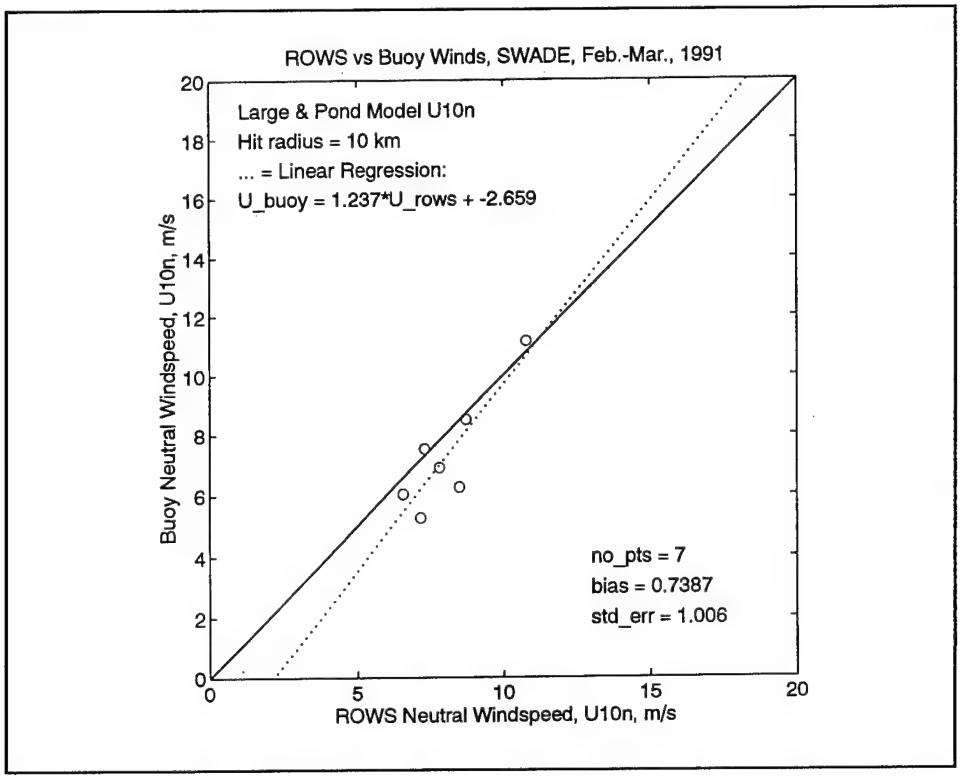

Figure 11. (c) 10-km proximity circle (Concluded)

5 ROWS Spectra

Appendix E contains ROWS directional and nondirectional spectra plots for the 12 T-39 flights in the period 12 February - 7 March, 1991. The appendix also contains flight line maps, navigation and file location data sheets, and weather maps (Appendix F) for each flight day. The spectra are plotted in the same format as the buoy spectra in Appendix D. This has resulted in some loss of detail in many of the spectra because of the high frequency range of the plots (outermost frequency ring = 0.4 Hz). For the SWADE priority day (March 5), however, plots with a maximum frequency of 0.2 Hz have been included to permit a better display of the complex modal structure in the energy-containing region of these spectra. All spectra in Appendix E have been produced using an isotropic sensitivity coefficient α based on interpolated A-mode *MSS* data as discussed in Chapters 3 and 4.

Each directional spectrum plot in Appendix E is accompanied by a wind speed (*W*) and a peak and mean direction (*pd* and *md*) estimate; each nondirectional spectrum plot is accompanied by a wave height (Hs) and a peak period (*Tp*) estimate. The wind speed estimates are from the A-mode interpolation fields of neutral wind speed as discussed in Chapter 4. The spectral peak direction is the directional maximum at the peak frequency f_pknd of the nondirectional spectrum as obtained from a parabolic fit to the binned data. Similarly, f_pknd is obtained by parabolic fit to the nondirectional spectrum peak and the peak period is taken as $Tp = 1/\text{f_pknd}$. The mean direction and mean period are computed from the binned spectrum data according to the definitions

$$\bar{\phi} = a\tan\left(<\sin\phi> / <\cos\phi>\right) \tag{11a}$$

$$\bar{T} = <f^{-1}> \tag{11b}$$

where the moment $<\ldots> \equiv E_o^{-1} \iint(\ldots)\, E(f,\phi)\,df\,d\phi$. A low-frequency cutoff is imposed to ensure that spurious low-frequency content in the measured spectrum does not corrupt these estimates. All these derived products are contained in the DEL*.MAT files as shown in Table 4. Note that the peak period and direction data for the buoy spectra in Appendix D are simple bin values as defined in the original S_PLOT program. Thus they cannot be expected to agree with the more precise ROWS values.

Frequency-Direction Plots

Appendix E also contains frequency-direction plots for the four StV flights. The directional analysis consists of the following: After prewhitening the directional spectrum by multiplying by f^5 and smoothing the data in frequency in the rear-face region, the measured first and second angular harmonics for each frequency band are equated to the corresponding first and second harmonic values of an assumed cosine-power model directional distribution function

$$D(f,\phi) = D_o(s)\left[\cos\left((\phi - \phi_o)/2\right)\right]^{2s} \tag{12}$$

where D_o is a normalization constant (cf. Longuet-Higgins, Cartwright, and Smith 1963). Two estimates of the spread parameter, $s \equiv s_\alpha(f)$, and mean direction, $\phi_0 \equiv \phi_{o\alpha}(f)$ ($\alpha = 1,2$) result from equating the first two measured harmonics to the first two harmonics of Equation 12. From the estimated spread parameters, the corresponding half-power directional spreads are calculated according to

$$\Delta\phi = 4a\cos\left[(1/2)^{1/2s}\right] \tag{13}$$

The analysis approach was arrived at after testing a number of estimators for the mean direction as a function of frequency. These tests showed the phase angle of the second angular harmonic of the symmetrical radar directional spectrum to be the most stable estimator of mean direction; also, the second harmonic mean direction estimates were found to be very close to the average of the mean direction estimates from two alternative estimators. In the case of the polar-symmetric radar data, a meaningful, nonzero first harmonic can be inferred from the radar angular distribution only if the 180-deg directional ambiguity is removed. For the present analysis, a likely direction of travel is chosen on the basis of meteorology and buoy observations. The radar spectrum is then redefined as being nonzero only in the 180-deg direction band between the absolute minima in the symmetric spectrum in the appropriate half space (see also Jackson, Walton, and Peng (1985)). Restricting the direction band to 180 deg results in an isotropic limit for the first harmonic half-power spread of $\pi/(\pi\text{-}2)$, or $\Delta\phi_{iso} = 112.1$ deg.

The mean directions so computed tend to be unstable at higher frequency when the standard isotropic sensitivity is used. Thus for the directional analyses, we use an anisotropic sensitivity based on an anisotropic *MSS* as defined by Equation 3. For the aspect ratios and principal directions, the values given in Table 5 are assumed. The principal axis direction is taken be the average wind direction as represented in Figure 2. The aspect ratios are essentially educated guesses.

Table 5
Assumed Anisotropy for St. Valentine's Data

Flight	Time[1], UT	Direction, ϕ_1	Aspect Ration, R
No. 1 (Feb. 14a)	17:59-19:09 (14 Feb.)	039°	0.85
No. 2 (Feb. 14b)	01:28-02:41 (15 Feb.)	102°	0.95
No. 3 (Feb. 15)	20:34-22:34 (15 Feb.)	102°	0.80
No. 4 (Feb. 16)	14:33-16:27 (16 Feb.)	122°	0.80

[1] Times of first and last S-mode files.

Example Data Products

Figure 12 is an example of the kind of ROWS data products that are available with post-processing. The example file S11 is from the southern leg of the first StV flight on 14 February (see Appendix E flight maps for file locations). Here, the spectrum is represented in both polar (panel 'a') and rectangular forms (panel 'c'). Contouring is logarithmic. The directionally integrated spectrum is given in both linear-linear form (panel 'b') and in log-log form (panel 'd'). Panel 'f' is a frequency-direction plot for the spectrum. Panel 'e' shows the cosine-power model fit to the directional distribution at the spectrum peak.

The spectrum example is for a nearly fully developed sea (Jackson and Jensen 1995). As with most observed unimodal spectra, the directional distribution is well fitted by the model function (Equation 12). From the frequency-direction plot in panel 'f,' it is seen that the mean direction is nearly constant with frequency and equal to 4 deg true azimuth. The directional spreading (which, we note, has not been corrected here for finite system resolution) is about 60 deg at the spectral peak. The first harmonic spreads saturate at the isotropic limit of 112.1 deg around 0.2 Hz. From panel 'd' it is seen that the rear face of the nondirectional spectrum follows a f^4 power law out to about 0.2 Hz, beyond which frequency a spectral roll-off is evident. The f^4 power law behavior in the rear face region is typical of the ROWS data collected in SWADE.

Custer Diagrams

Synoptic views of the wave field in the SWADE area at the times of the four StV flights are presented in Figure 13 in the form of "Custer" diagrams, in which the ROWS and buoy-observed mean wave periods and directions are represented by arrows of various lengths and directions. In

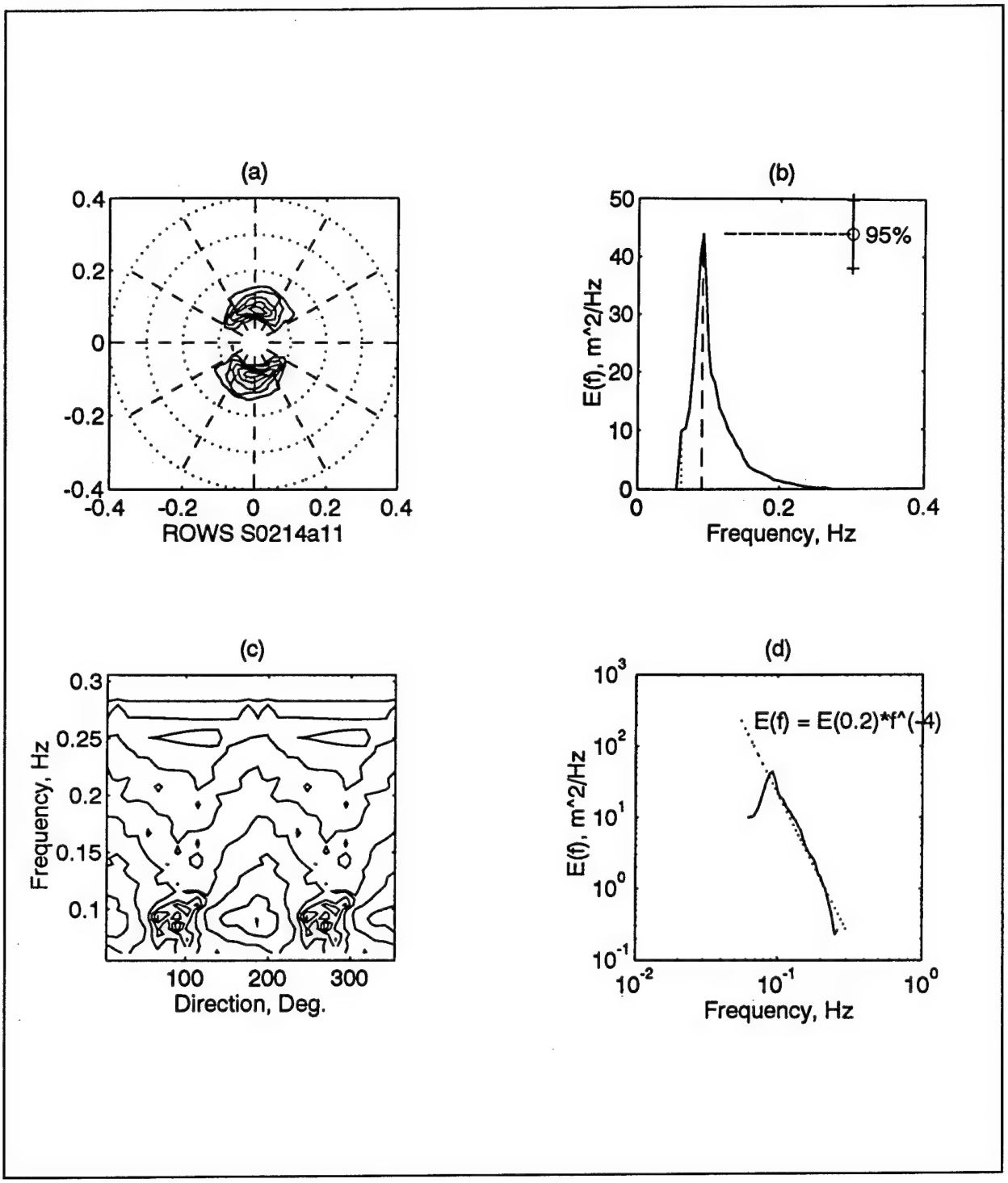

Figure 12. Detailed analysis of ROWS spectrum file S11 for flight No. 1 on 14 February: (a) Polar contour plot of directional energy spectrum, contour levels in 2.5-dB decrements from spectral peak and frequency axis scales in Hz, (b) Nondirectional energy (height-variance) spectrum, with 95-percent confidence interval for peak as indicated, (c) Rectangular contour plot of the directional spectrum with logarithmic contour spacing, (d) Log-log plot of nondirectional height spectrum with f^{-4} power-law (dotted line) (Continued)

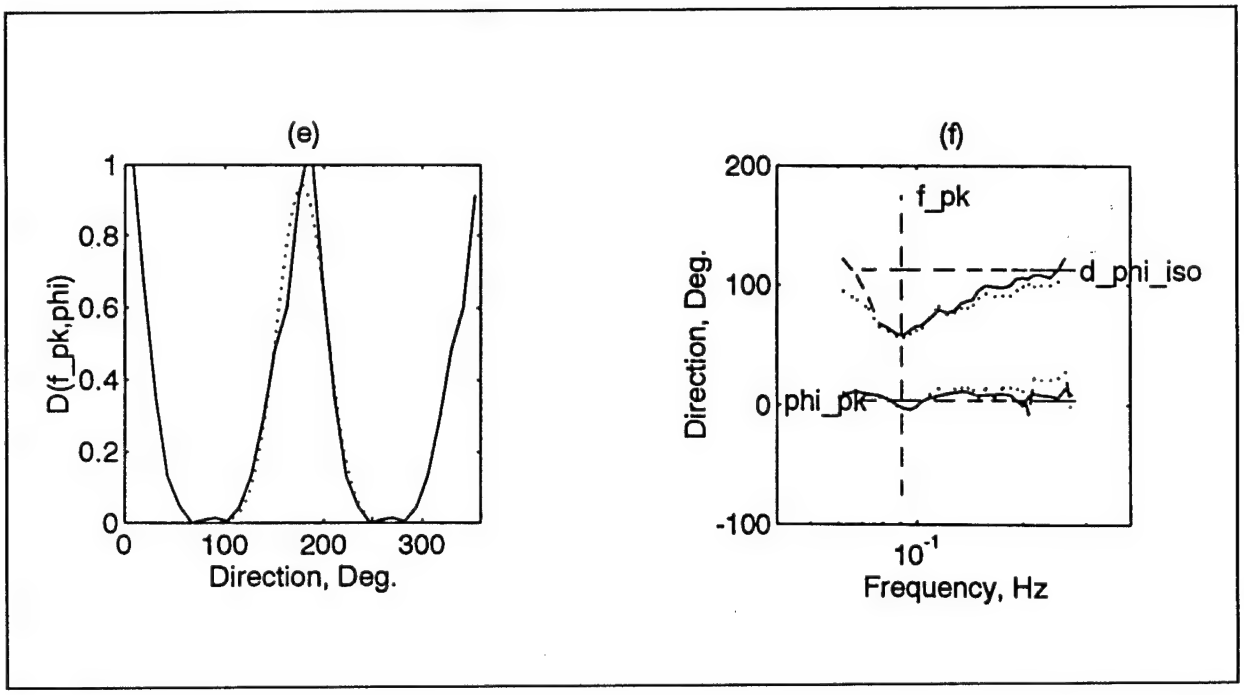

Figure 12. (e) Cosine-power model function fit (dotted curve) to the directional distribution at the peak of the nondirectional spectrum (solid curve), (f) Directional analysis: Lower curves are first (dotted lines) and second (solid line) harmonic phase angles; upper curves are the model function half-power full-widths (dotted line, first harmonic fit; solid line, second harmonic fit). f_pk is the frequency of the peak of the nondirectional spectrum; phi_pk is the peak direction at f = f_pk; and d_phi_iso is the isotropic limit for the first-harmonic directional half-power spreading (Concluded)

these figures, the coastline of the southern MAB is idealized as two straight lines, one running north and one south from Cape Henry, VA. The notch in the northern coastline is meant to represent the added fetch area associated with the Delaware Bay. Mean wave directions and periods are computed from the radar and buoy directional spectra according to the definitions in Equation 11.

Fetch-Limited Data

The StV wind-turning event concludes on 16 February with strong, steady northwesterly winds. By the time of the fourth StV flight on the 16th, the wave field has adjusted to the new fetch-limited conditions. The Custer diagram for this flight shows the mean wave vectors on the southern flight leg to be aligned with the mean wind direction of 122 deg (direction *to*). On the northern flight leg, the mean wave directions are rotated some 10-30 deg northward of the wind direction. This may be an effect of the Delaware Bay (Jackson and Jensen 1995).

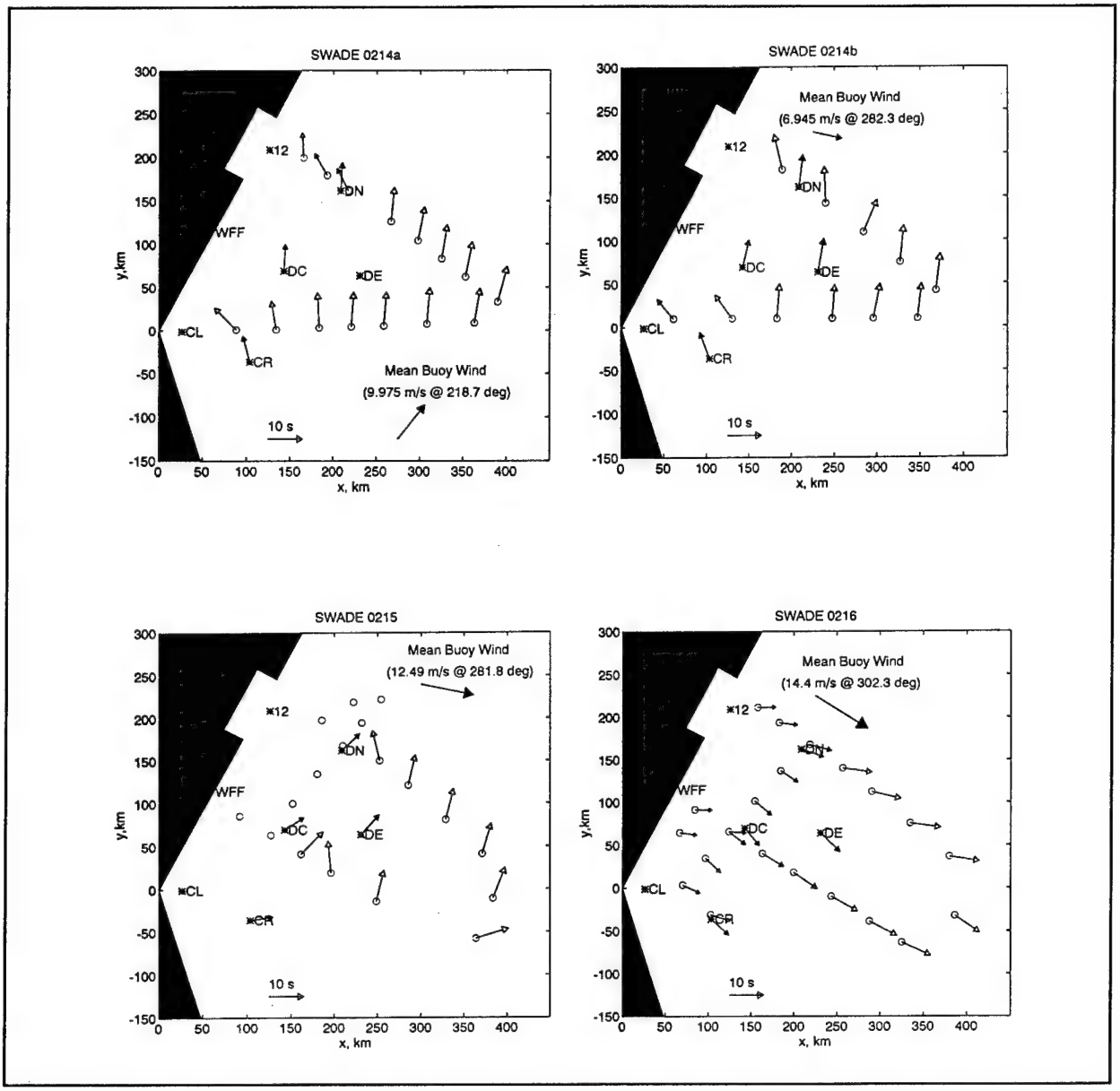

Figure 13. Custer diagrams of the mean wave vectors (mean directions and periods) for the four ROWS St. Valentine's flights (o = radar data; * = buoy data) on a Cartesian map with idealized coastline. The notch in the northern coastline represents an added fetch area associated with the Delaware Bay

In Figure 14, the wave energy and peak frequency for all radar and buoy observations at the time of the fourth StV flight on 16 February are plotted in nondimensional form as a function of the fetch normal to the idealized northern coastline. Data for both frequency and energy show an approach to the Pierson-Moskowitz (PM) limits around the largest observed fetch of about 375 km. These limits are computed assuming a wind speed of U_{10n} = 13.7 m/s, which is the mean wind speed for ROWS files S05-12. The buoy and radar data agree fairly well, except near the

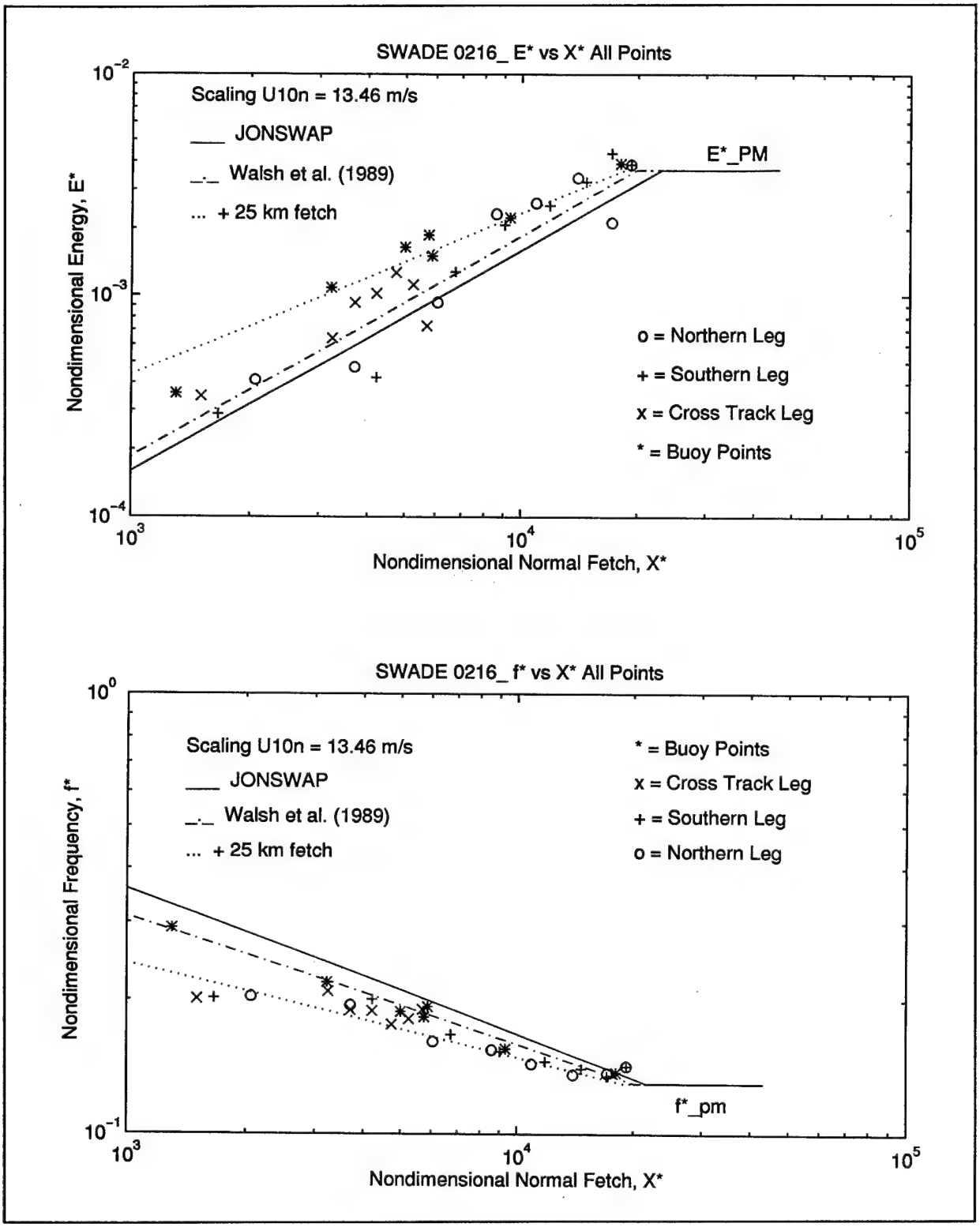

Figure 14. Radar and buoy nondimensional energy (upper panel) and peak frequency (lower panel) data versus nondimensional fetch for 16 February 1991 with empirical growth laws. The curve for the extra 25-km fetch is intended to model the possible effect of the added fetch region around the mouth of Delaware Bay

shelf break, where the buoys are relatively high in both energy and frequency compared to the radar observations. The discrepancies here may be due to poor ROWS response in low sea states. They may also be due to wave field variability in the vicinity of the shelf break. However, similar discrepancies have been observed with the SCR[1]; thus, it is quite possible that the buoy data are in error.[2]

Nondimensional fetch, frequency, and energy are given, respectively, by

$$X^* = \left(g / U_{10n}^2\right) X \tag{14a}$$

$$f^* = \left(U_{10n} / g\right) f \tag{14b}$$

$$E^* = \left(g^2 / U_{10n}{}^4\right) E \tag{14c}$$

where $E \equiv \mathrm{SWH}^2$. A scaling wind speed of U_{10n} = 13.7 m/s is assumed. As seen in Figure 14, the nondimensional energy data agree fairly well with the JONSWAP linear fetch law, $E^* = 1.60 \times 10^{-7} X^*$, but the peak frequency data differ significantly from the JONSWAP fetch law, viz. $f^* = 3.5\, X^{*-0.33}$ (Hasselmann et al. 1973). The ROWS data in both energy and frequency are seen to agree better with the modified fetch laws proposed by Walsh et al. (1989), namely, $E^* = 1.86 \times 10^{-7} X^*$ and $f^* = 2.3\, X^{*-0.29}$

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1 Personal communication, E. Walsh, NASA/Wallops Flight Facility, Wallops Island, Virginia. On assignment at the NOAA/ERL Wave Propagation Laboratory, Boulder, CO.

2 Note in proof: recently reprocessed data for discus E and C show better agreement with the data; however, the buoy wave heights and frequency data remain higher than the ROWS data.

6 Conclusion

This report presents all ROWS wind and wave data that have been processed for SWADE. The production of more data is unlikely given that the author is no longer with NASA. ROWS data reduction for SWADE was unusually demanding. Over 3 months were taken in the manual reduction of the navigation and file data alone. The data processing itself required manual intervention to establish the zero degree azimuth offset. Scaling of the spectra required interpolation of altimeter mode data to the spectrometer mode file locations.

Since the SWADE experiment, work on the ROWS system has eliminated the sources of the aforementioned difficulties in data collection and data reduction. Antenna shaft encoder data are now properly recorded; navigation data are now electronically logged; switching to the altimeter mode now is automatic[1] so that the spectrum data can be easily scaled; the digitizer is now properly synchronized with the radar so that wave height data are available directly from the altimeter mode data (albeit with only 10 ns resolution; cf. Vandemark et al. (1994a,b)).

ROWS data quality for SWADE is generally quite good. The only problems encountered with the data are: (a) 'dc' contamination of the spectra in low sea state cases (wave heights less than 2 m) and (b) directional broadening of the spectra caused by aircraft altitude variations. It is possible also that some of the spectra are poorly scaled. Poor scaling may occur in cases where large wind and/or wave field gradients exist between the spectra observations and the altimeter mode observations used to scale the spectra. These problems should not detract from the usefulness of the data for a number of possible SWADE investigations. The most interesting set of ROWS data collected in SWADE is from the St. Valentine's Day wind/wave event. The fetch diagrams of Figure 14 from the fourth St. Valentine's flight provide an example of the usefulness of the ROWS SWADE data for wave research.

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[1] A ferrite switch switches between the two ROWS antennas on an alternate pulse basis. Thus ROWS operates continuously with a 50 percent duty cycle, that is with 50 pulses per second for each ROWS mode.

Since 1993, ROWS spectra (*.SRF files) and altimeter data (*.OUT files) have been archived at the NASA/WFF SWADE Data Archive Center. With the publication of this report, additional ROWS data such as the spectrum scaling data will be made available to the public in electronic format.

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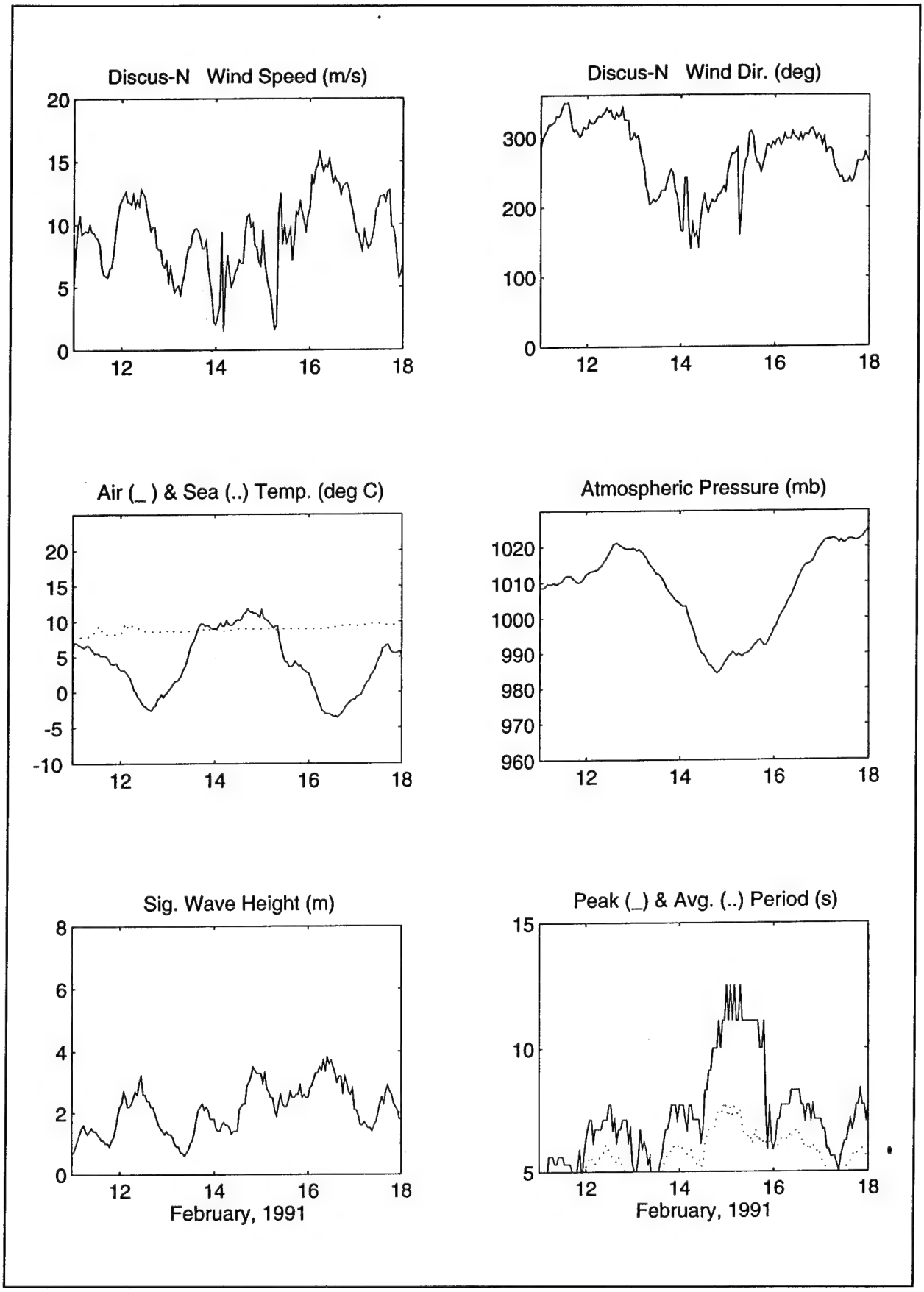
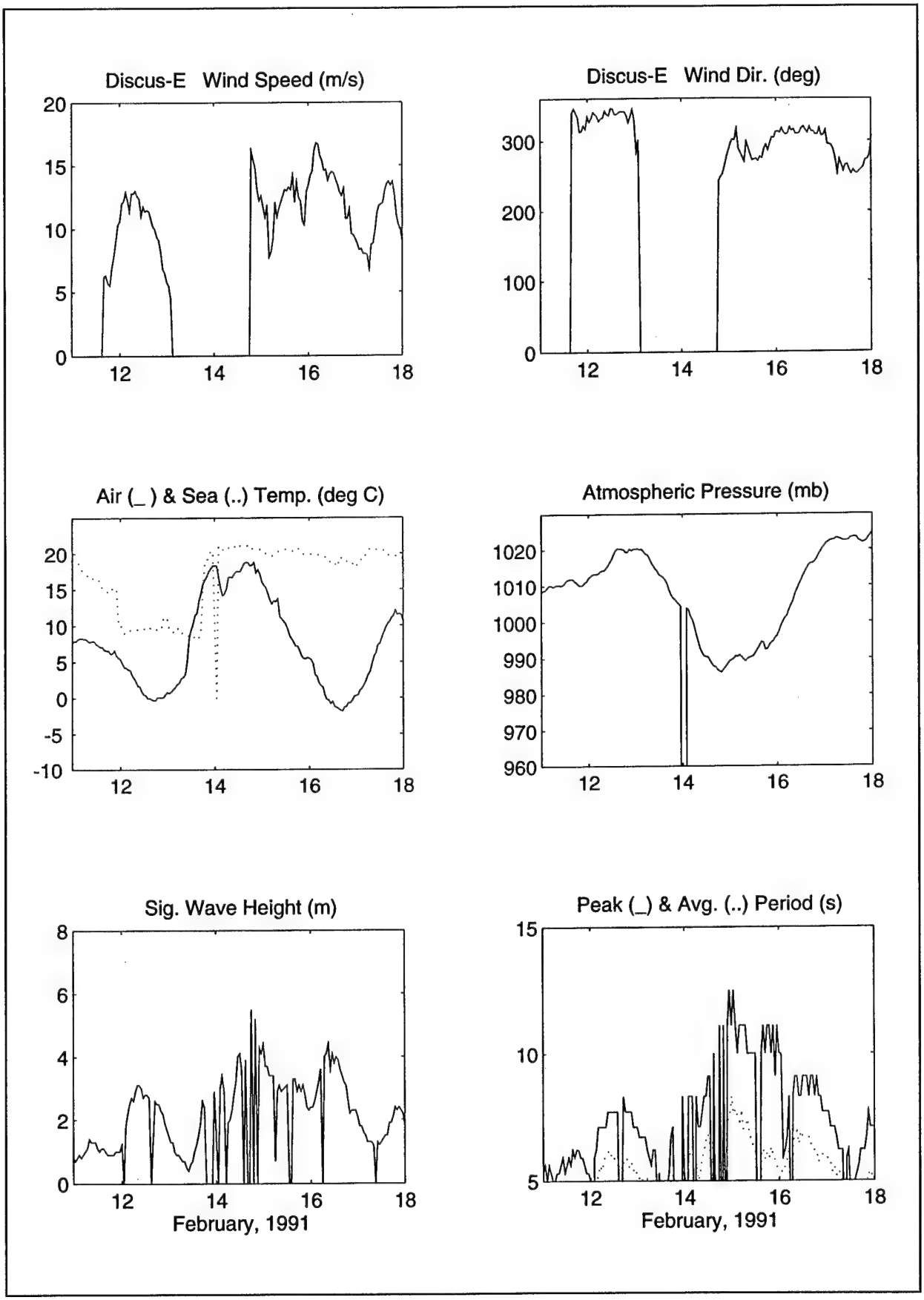
Appendix A
Buoy Environmental Data, 11-18 February 1991

This appendix contains time series of buoy environmental data for the St. Valentine's observational period. These data are also contained in the report by Caruso et al. (1994); however, the time scale there is compressed, making the data for this interesting period difficult to read. The data presented here are for nine platforms. The locations of these data collection platforms are given in Table 1 in the main text.

Note that the buoy mean periods are plotted here according to the second moment definition. Buoy mean periods for the Custer diagrams of Figure 13 are according to the first moment definition, Equation 11b.


Discus-N Wind Speed (m/s)
20
15
10
5
0
12
14
16
18
Discus-N Wind Dir. (deg)
300
200
100
0
12
14
16
18
Air (_) & Sea (..) Temp. (deg C)
20
15
10
5
0
-5
-10
12
14
16
18
Atmospheric Pressure (mb)
1020
1010
1000
990
980
970
960
12
14
16
18
Sig. Wave Height (m)
8
6
4
2
0
12
14
16
18
February, 1991
Peak (_) & Avg. (..) Period (s)
15
10
5
12
14
16
18
February, 1991


Discus-E Wind Speed (m/s)
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12
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16
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Discus-E Wind Dir. (deg)
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18
Air (_) & Sea (..) Temp. (deg C)
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0
-5
-10
12
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16
18
Atmospheric Pressure (mb)
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990
980
970
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Sig. Wave Height (m)
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February, 1991
Peak (_) & Avg. (..) Period (s)
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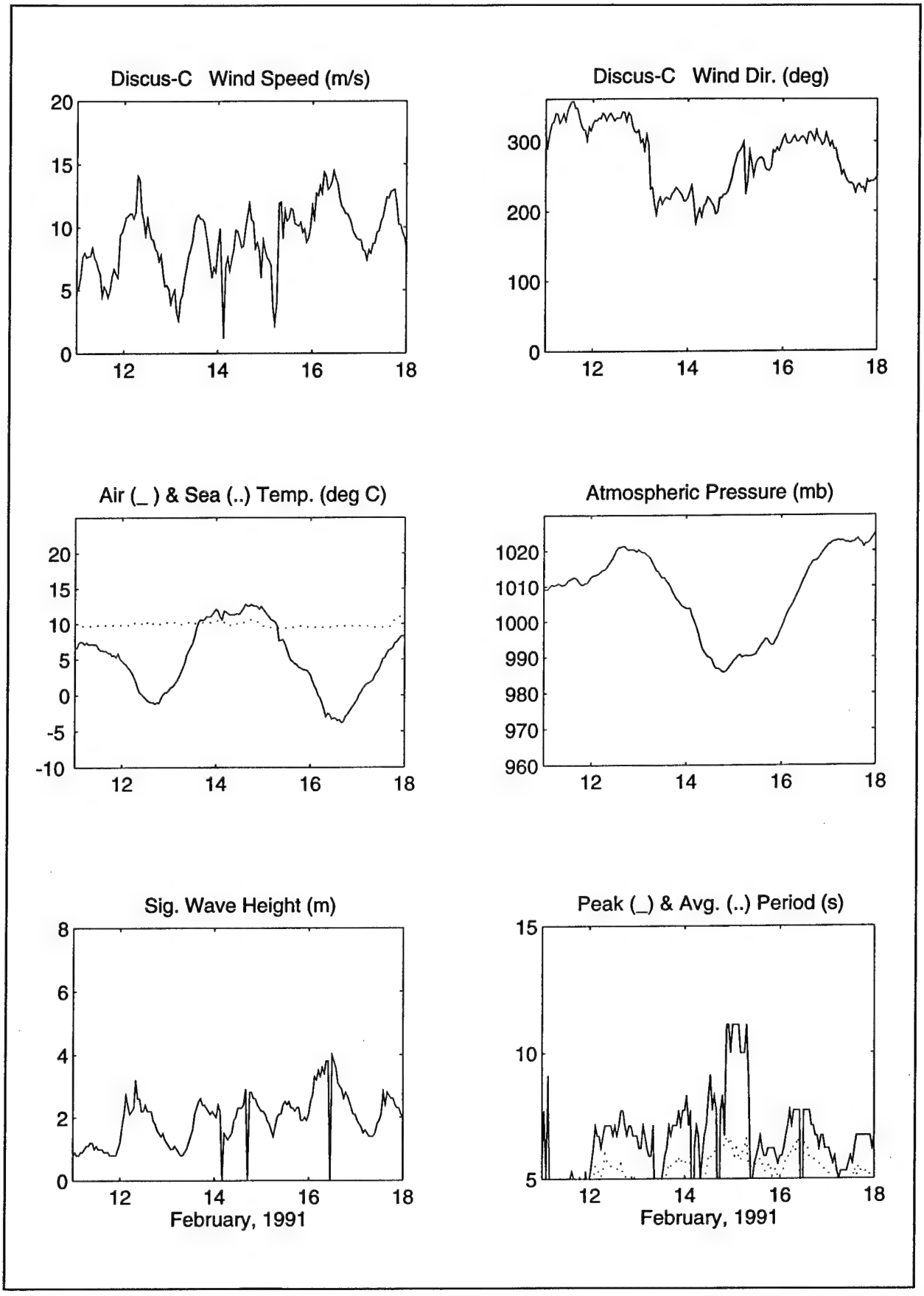
February, 1991


Discus-C Wind Speed (m/s)
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Discus-C Wind Dir. (deg)
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14
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18
Air (_) & Sea (..) Temp. (deg C)
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-10
12
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16
18
Atmospheric Pressure (mb)
1020
1010
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990
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16
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Sig. Wave Height (m)
8
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February, 1991
Peak (_) & Avg. (..) Period (s)
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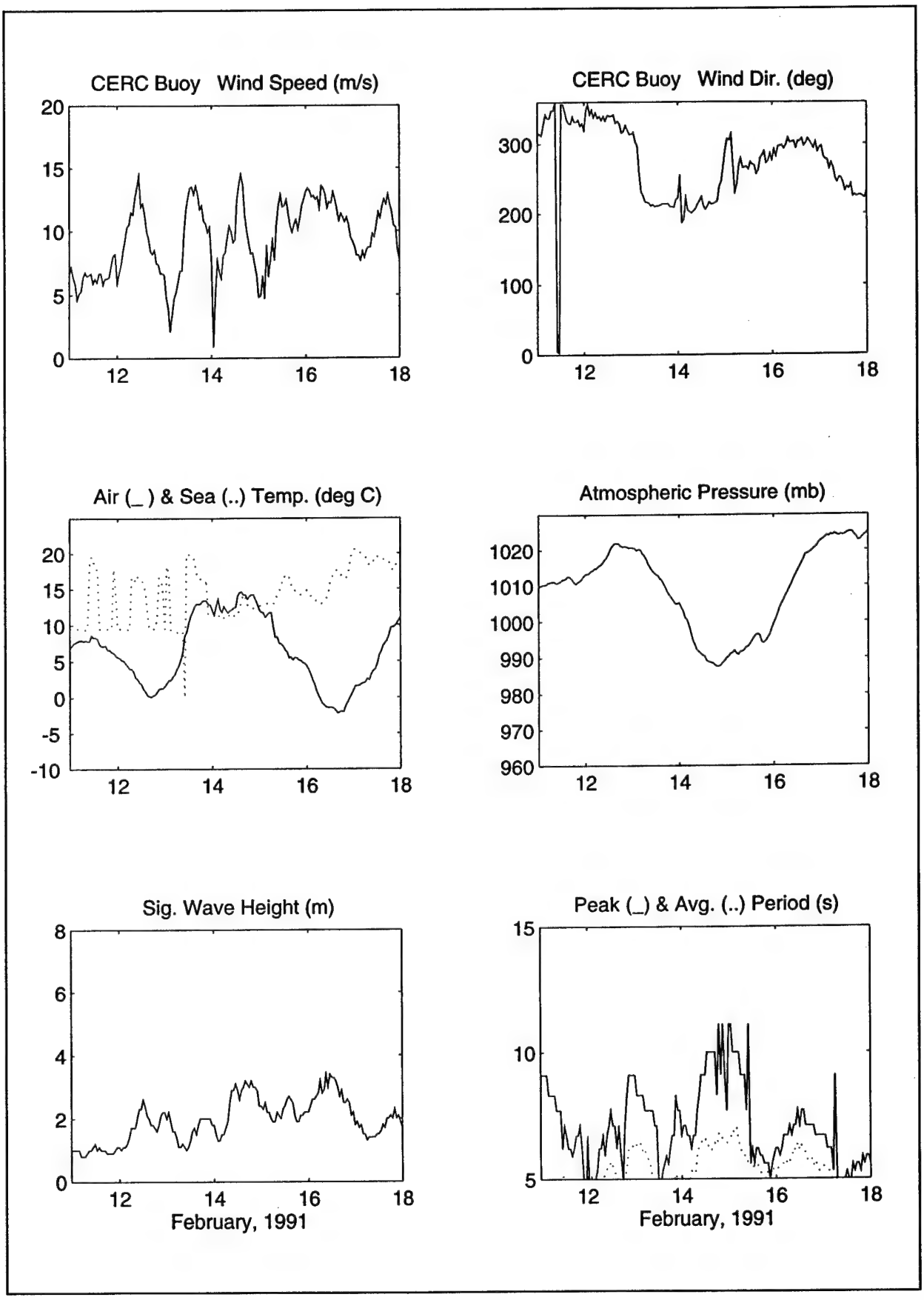
February, 1991


CERC Buoy Wind Speed (m/s)
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CERC Buoy Wind Dir. (deg)
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Air (_) & Sea (..) Temp. (deg C)
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Atmospheric Pressure (mb)
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Sig. Wave Height (m)
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February, 1991
Peak (_) & Avg. (..) Period (s)
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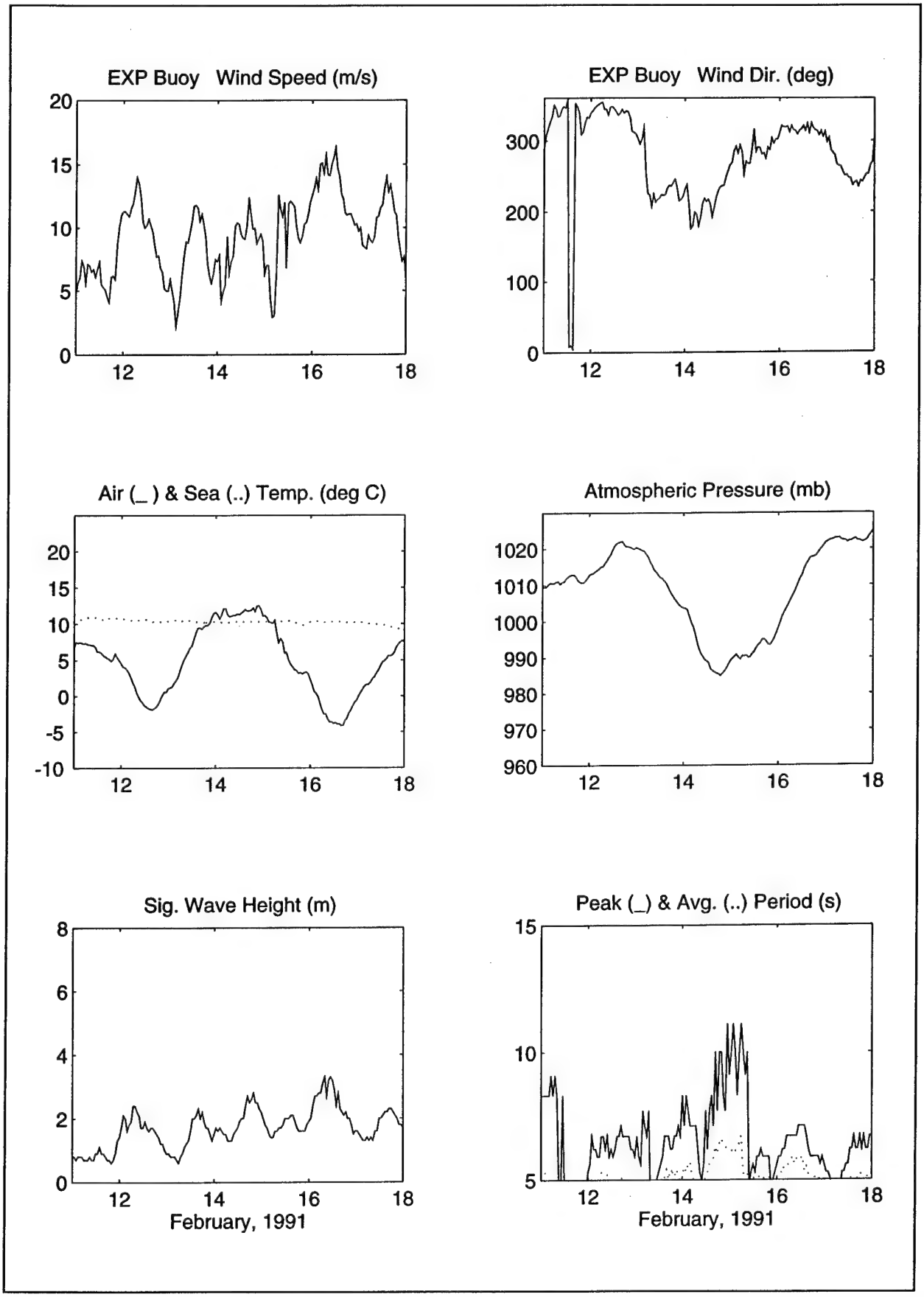
February, 1991


EXP Buoy Wind Speed (m/s)
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EXP Buoy Wind Dir. (deg)
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Air (_) & Sea (..) Temp. (deg C)
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Atmospheric Pressure (mb)
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Sig. Wave Height (m)
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February, 1991
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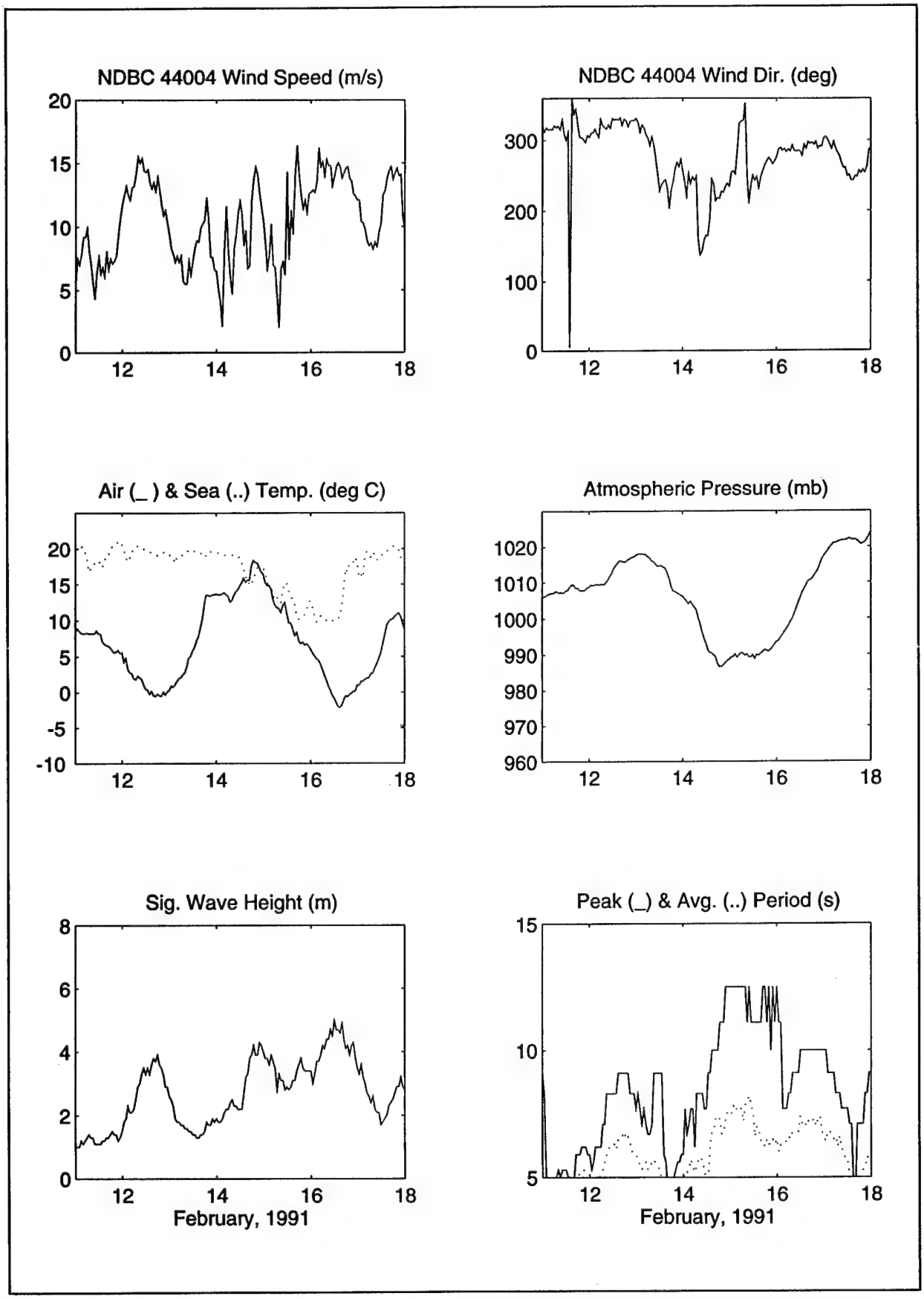
February, 1991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NDBC 44004 Wind Dir. (deg)
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Air (_) & Sea (..) Temp. (deg C)
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Atmospheric Pressure (mb)
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Sig. Wave Height (m)
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February, 1991
Peak (_) & Avg. (..) Period (s)
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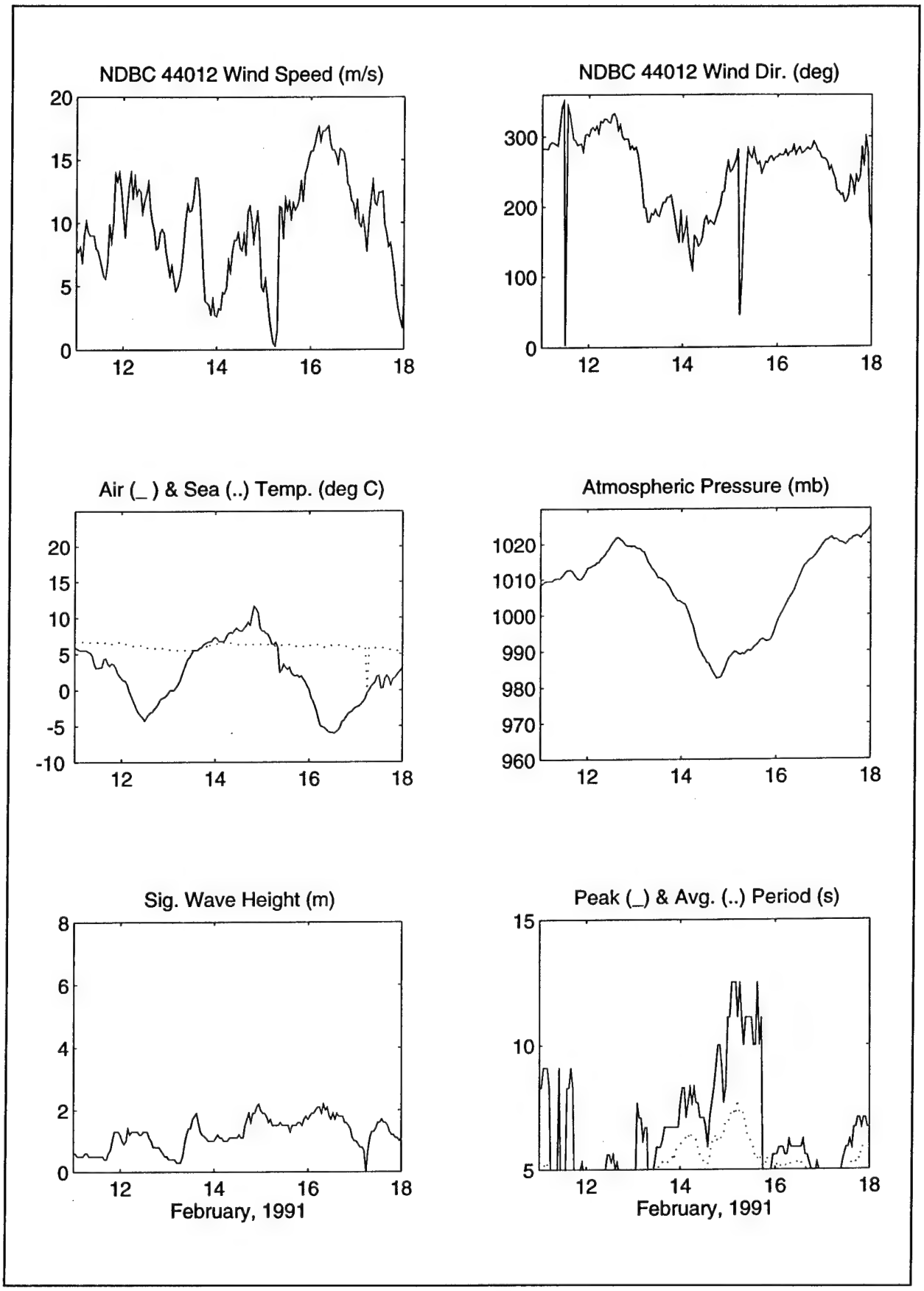
February, 1991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NDBC 44012 Wind Dir. (deg)
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Air (_) & Sea (..) Temp. (deg C)
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Atmospheric Pressure (mb)
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Sig. Wave Height (m)
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February, 1991
Peak (_) & Avg. (..) Period (s)
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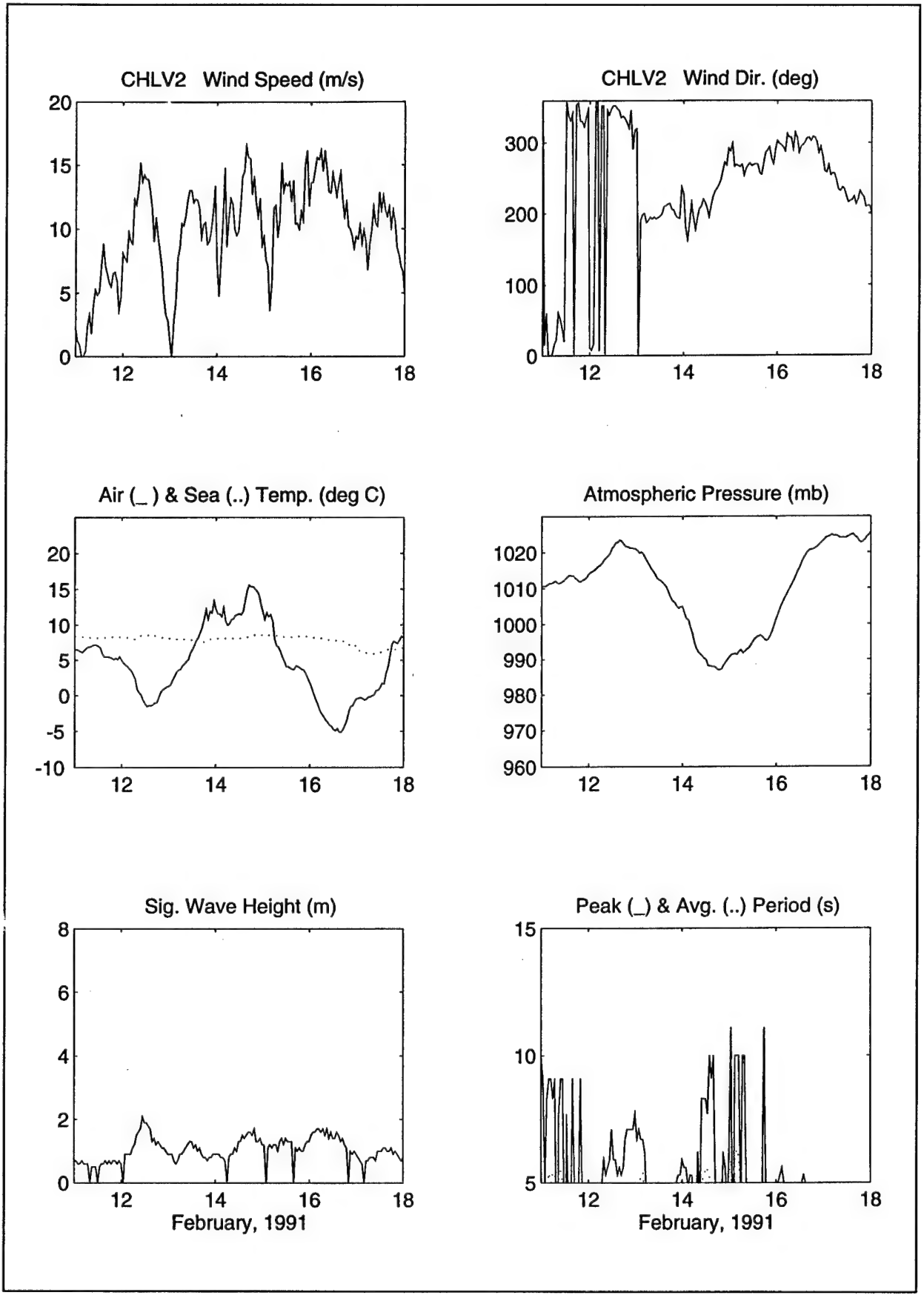
February, 1991


CHLV2 Wind Speed (m/s)
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CHLV2 Wind Dir. (deg)
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Sig. Wave Height (m)
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February, 1991
Peak (_) & Avg. (..) Period (s)
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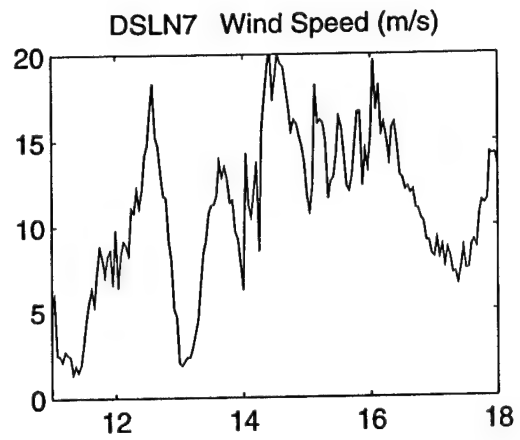
February, 1991


DSLN7 Wind Speed (m/s)
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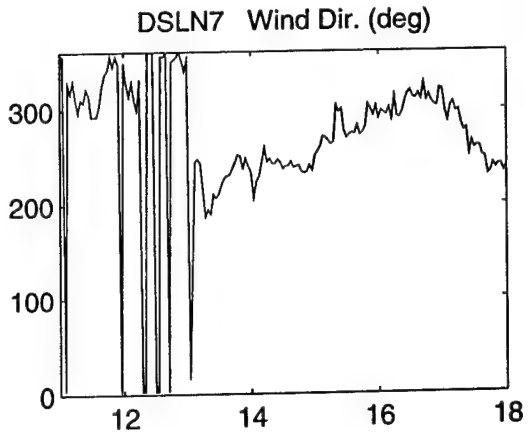
DSLN7 Wind Dir. (deg)
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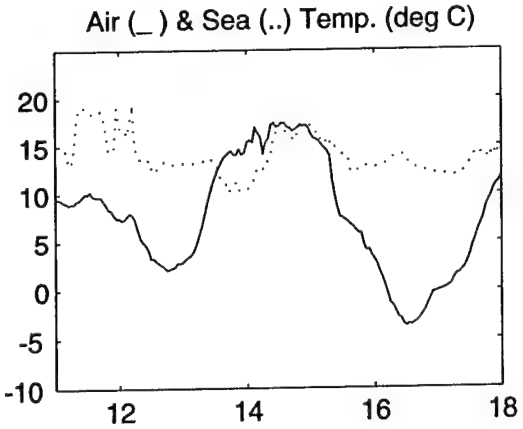
Air (_) & Sea (..) Temp. (deg C)
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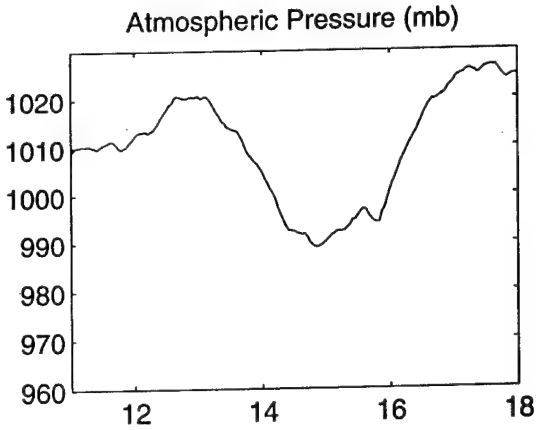
Atmospheric Pressure (mb)
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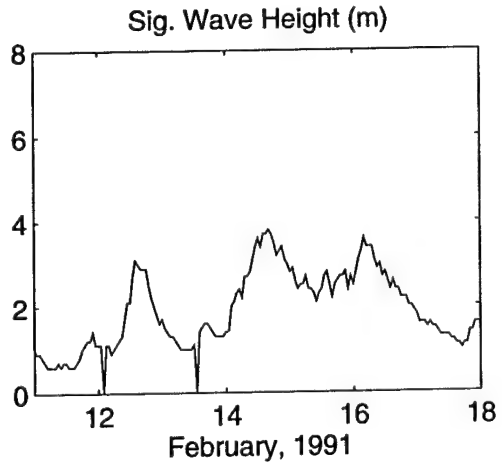
Sig. Wave Height (m)
8
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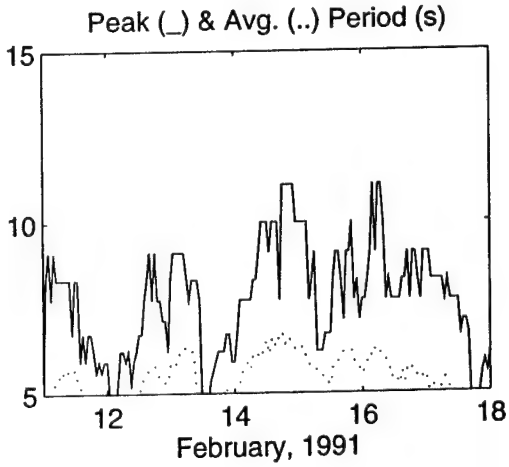
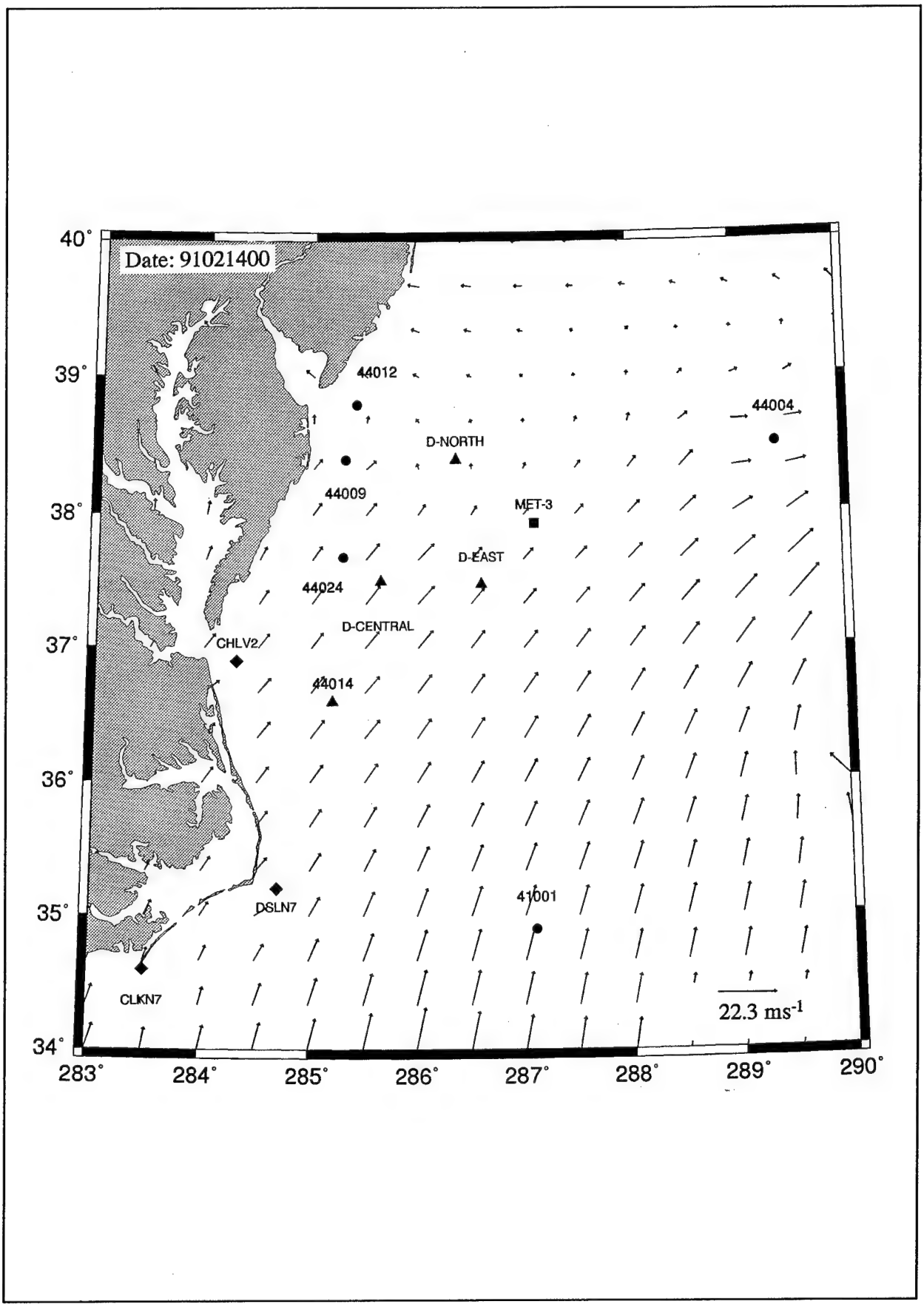
18
February, 1991


Peak (_) & Avg. (..) Period (s)
15
10
5
12
14
16
18
February, 1991

Appendix B
NMC Wind Fields, 14-16 February 1991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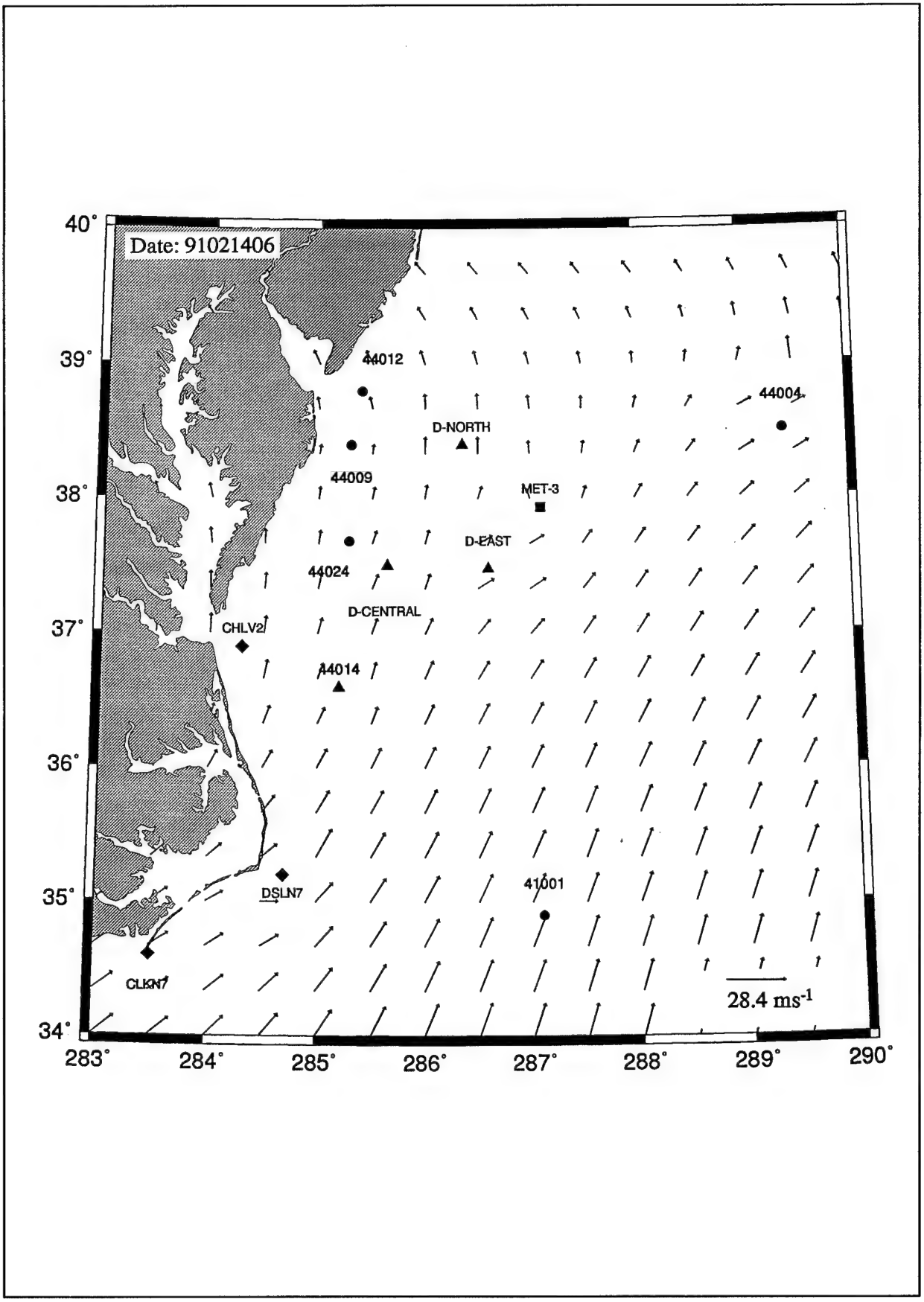
40°
39°
38°
37°
36°
35°
34°
283°
284°
285°
286°
287°
288°
289°
290°
44012
44004
D-NORTH
44009
MET-3
D-EAST
44024
D-CENTRAL
CHLV2
44014
DSLN7
41001
CLKN7
22.3 ms-1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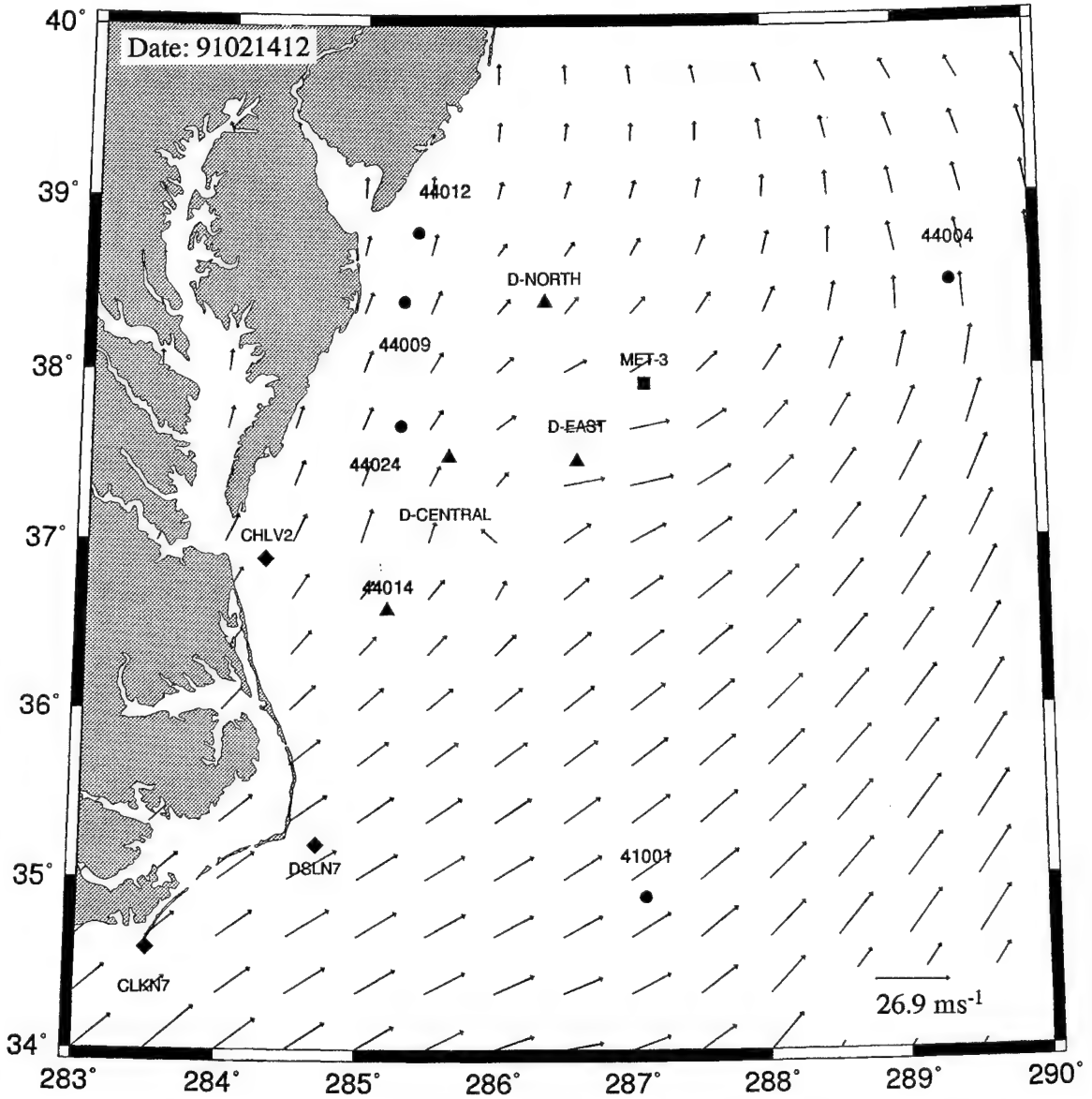
289°
290°
44012
44004
D-NORTH
44009
MET-3
D-EAST
44024
D-CENTRAL
CHLV2
44014
DSLN7
41001
CLKN7
28.4 ms-1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38°
37°
36°
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286°
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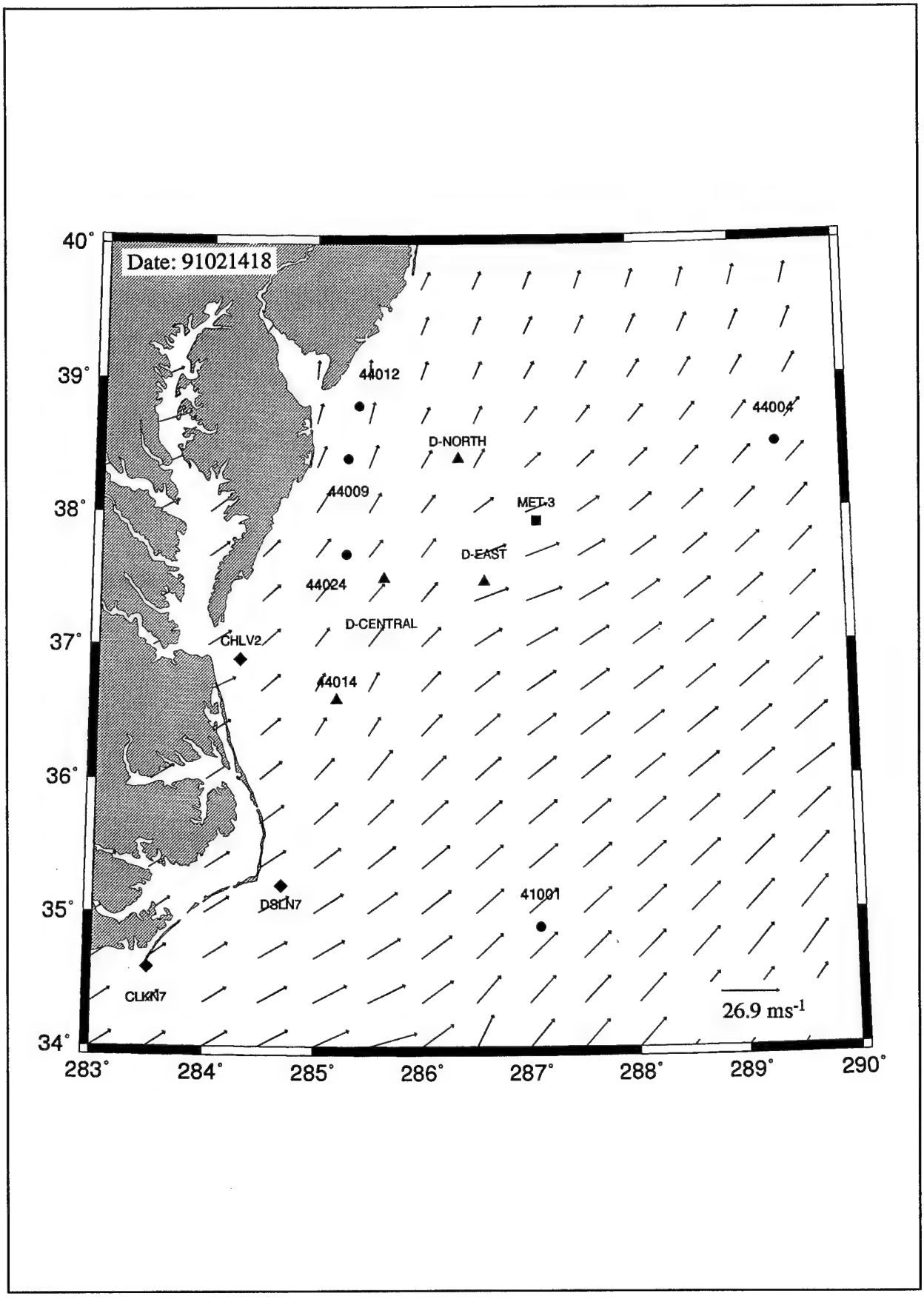
289°
290°
44012
44004
D-NORTH
44009
MET-3
D-EAST
44024
D-CENTRAL
CHLV2
44014
DSLN7
41001
CLKN7
26.9 ms-1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38°
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35°
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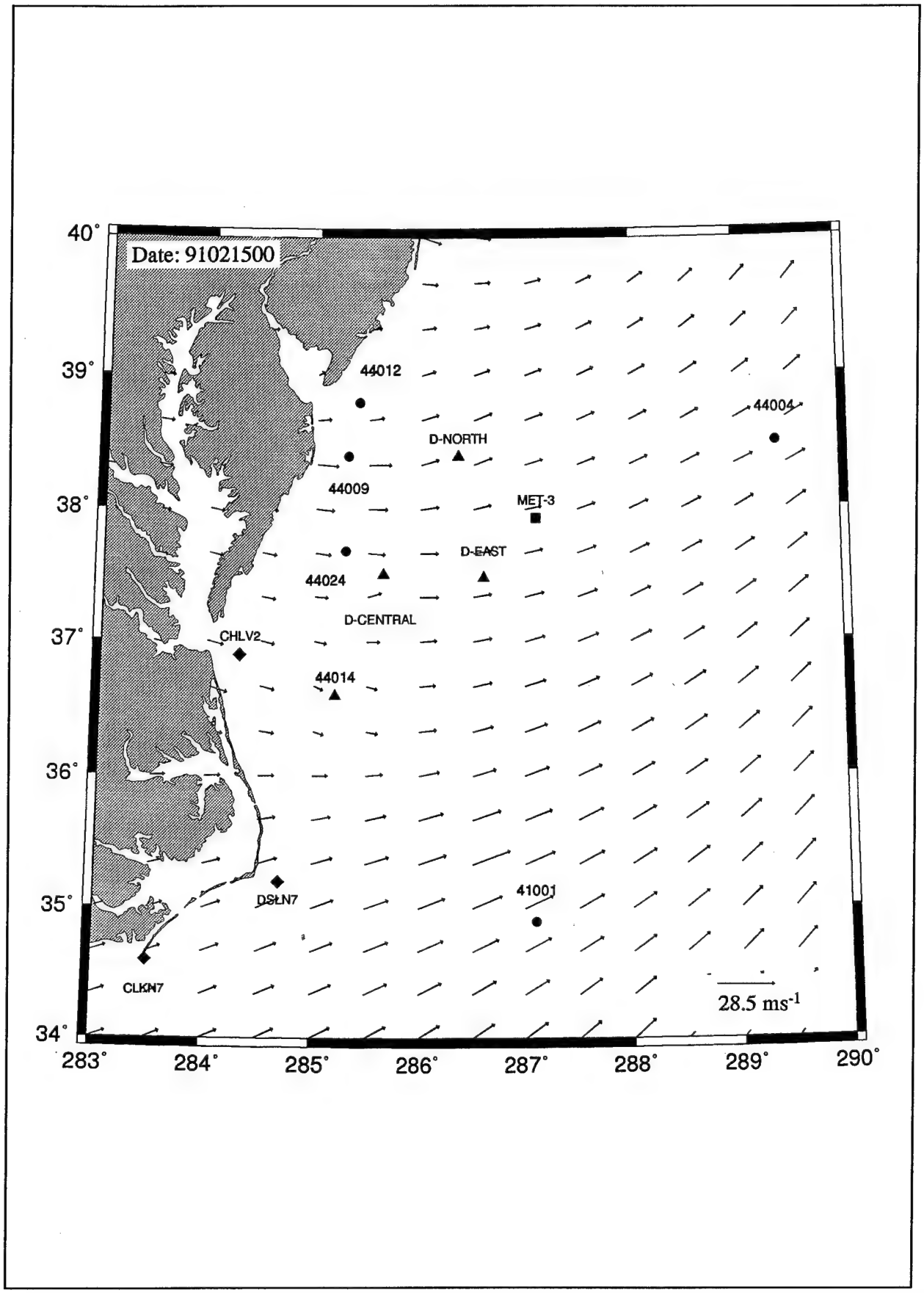
287°
288°
289°
290°
44012
44004
D-NORTH
44009
MET-3
D-EAST
44024
D-CENTRAL
CHLV2
44014
41001
DSLN7
CLKN7
26.9 ms-1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38°
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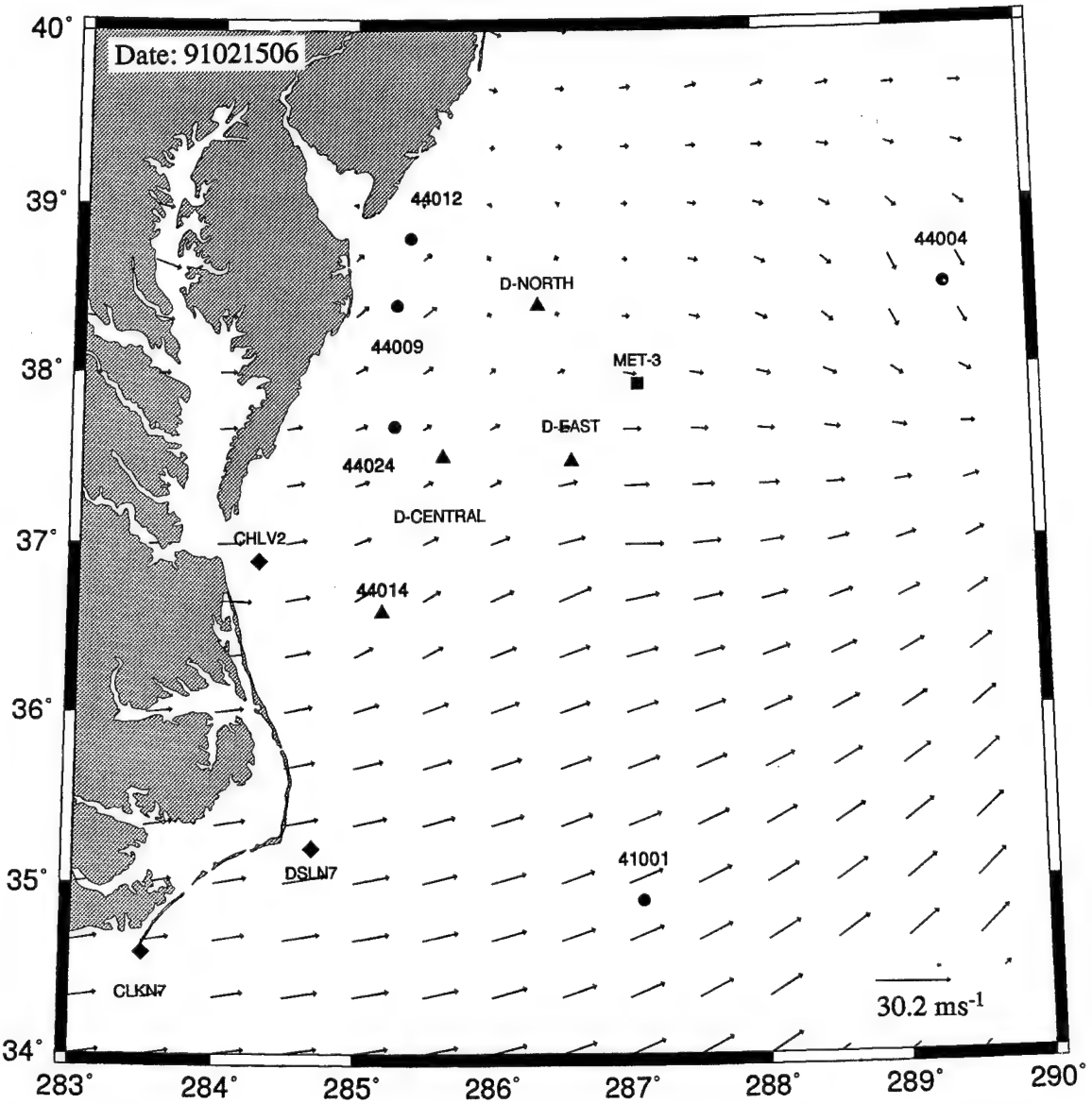
287°
288°
289°
290°
44012
44004
D-NORTH
44009
MET-3
D-EAST
44024
D-CENTRAL
CHLV2
44014
DSLN7
41001
CLKN7
28.5 ms-1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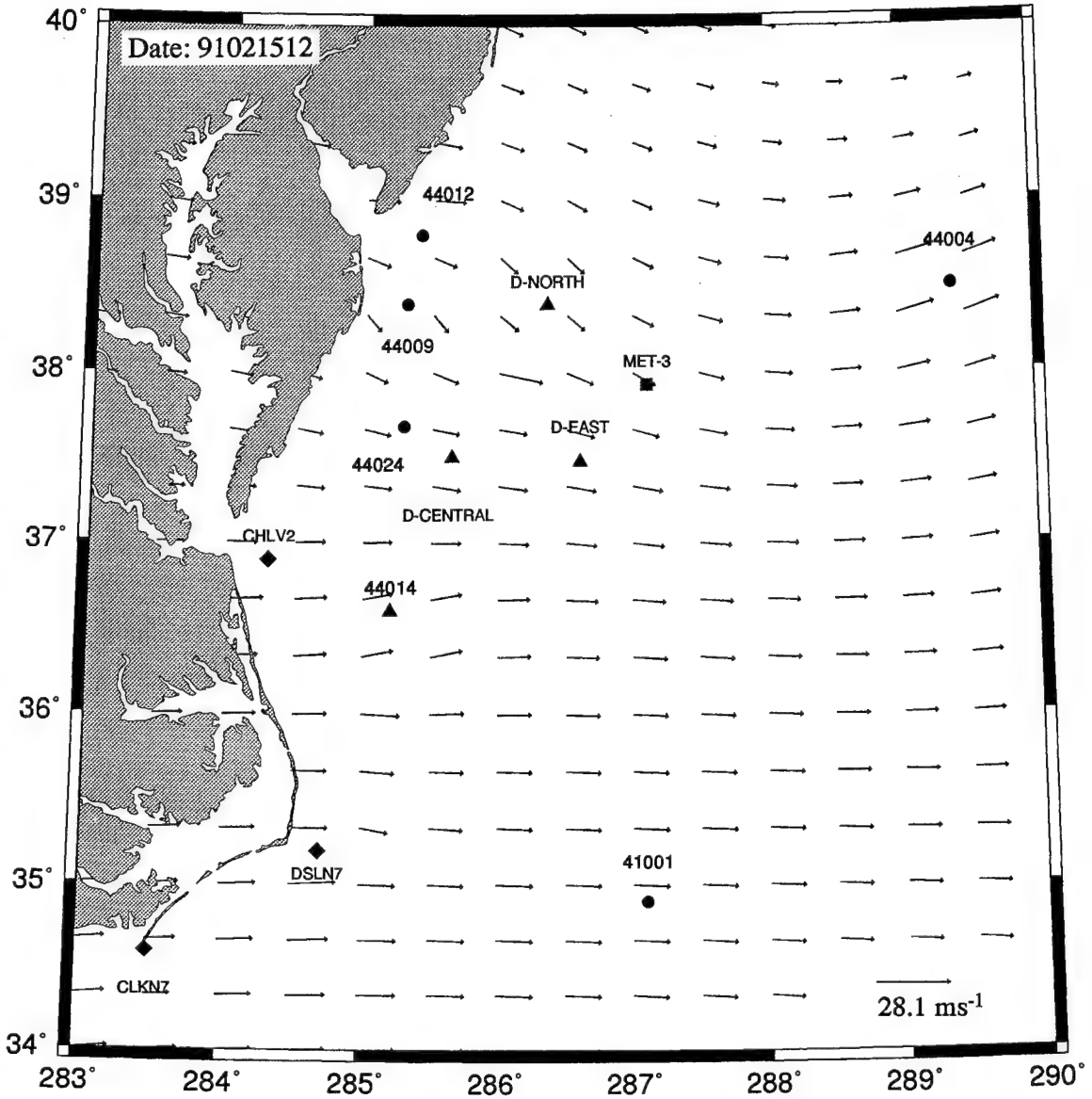
289°
290°
44012
44004
D-NORTH
44009
MET-3
D-EAST
44024
D-CENTRAL
CHLV2
44014
DSLN7
41001
CLKN7
30.2 ms-1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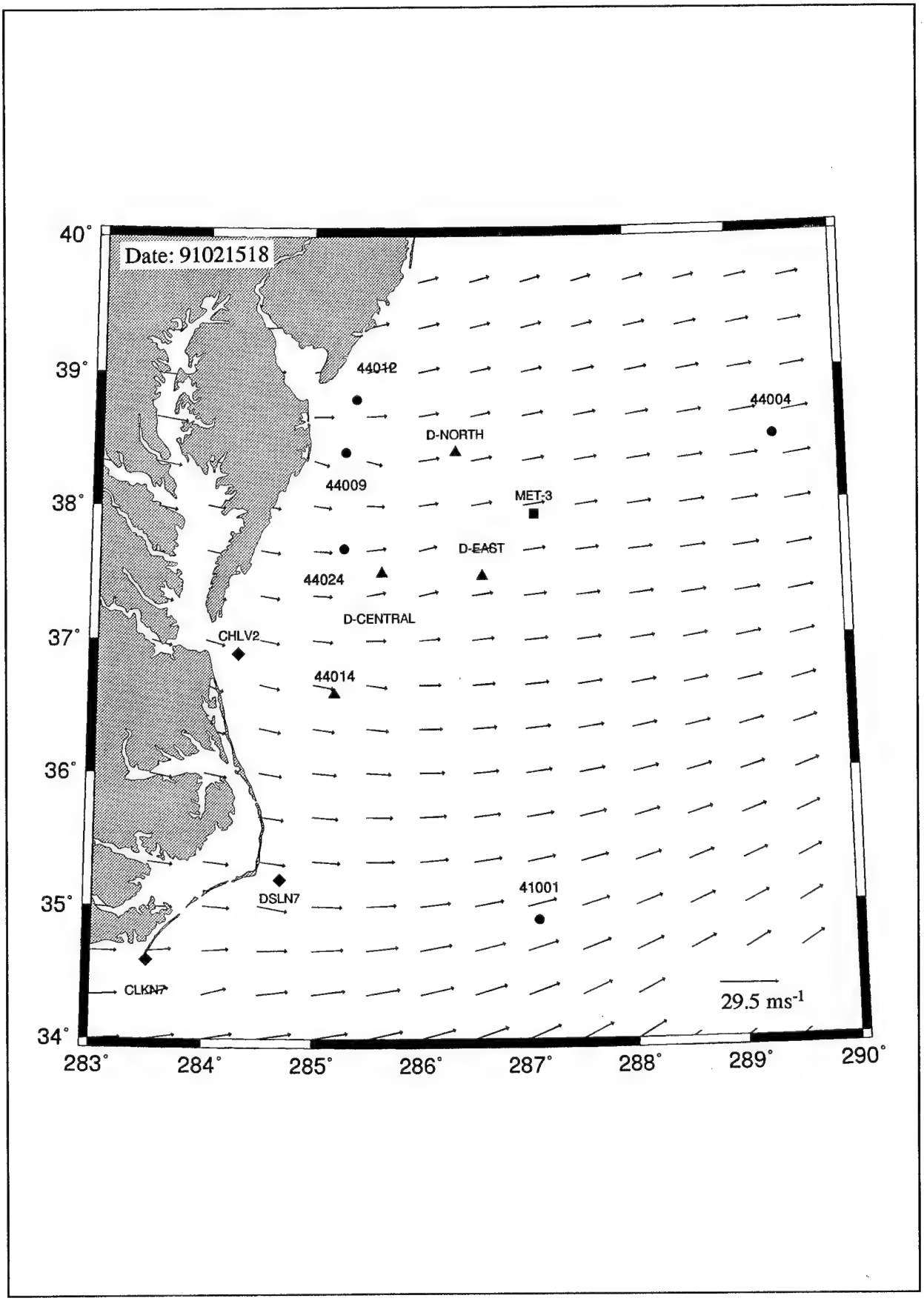
286°
287°
288°
289°
290°
44012
44004
D-NORTH
44009
MET-3
D-EAST
44024
D-CENTRAL
CHLV2
44014
DSLN7
41001
CLKNZ
28.1 ms-1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36°
35°
34°
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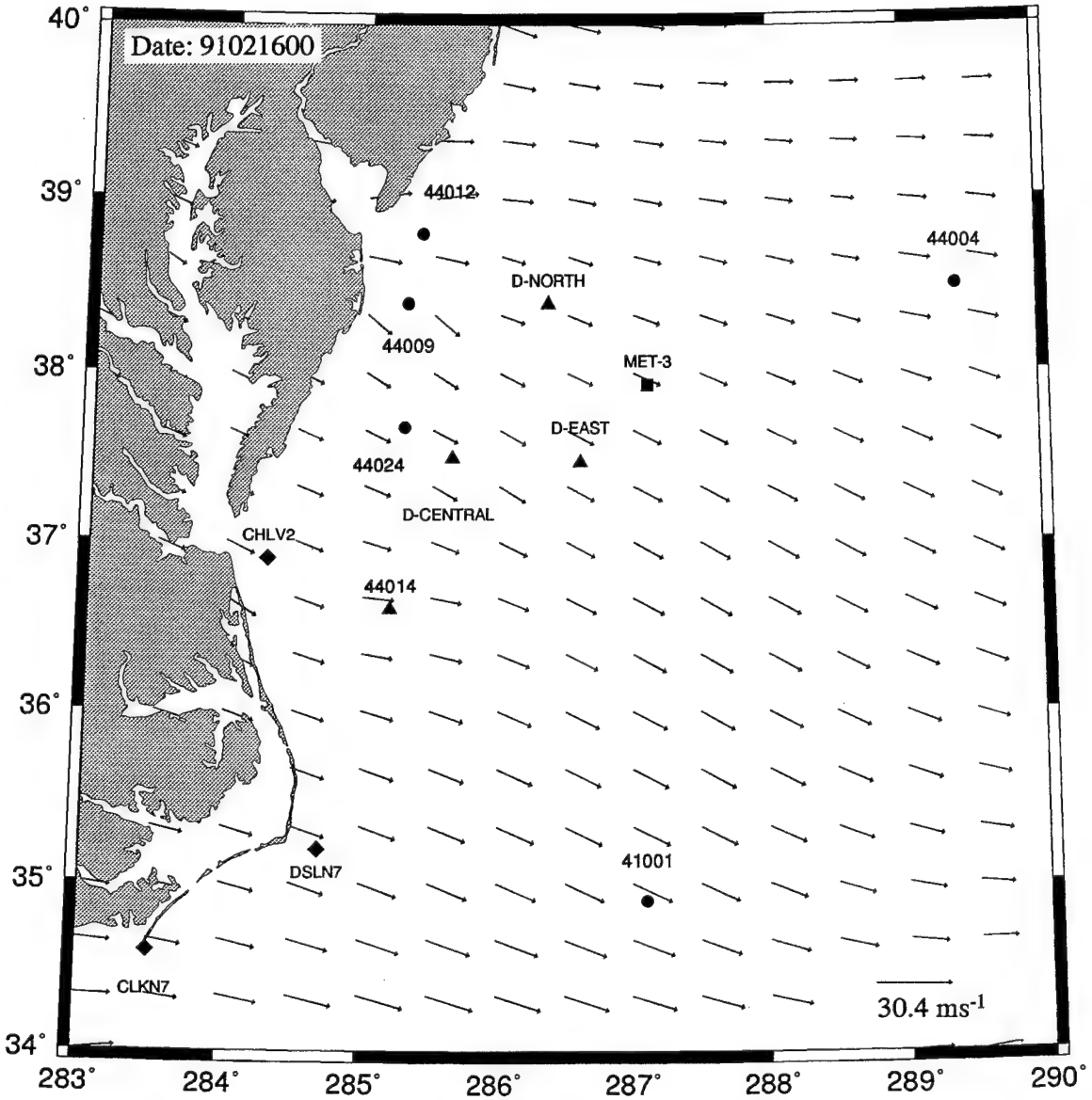
284°
285°
286°
287°
288°
289°
290°
44012
44004
D-NORTH
44009
MET-3
D-EAST
44024
D-CENTRAL
CHLV2
44014
DSLN7
41001
CLKN7
29.5 ms-1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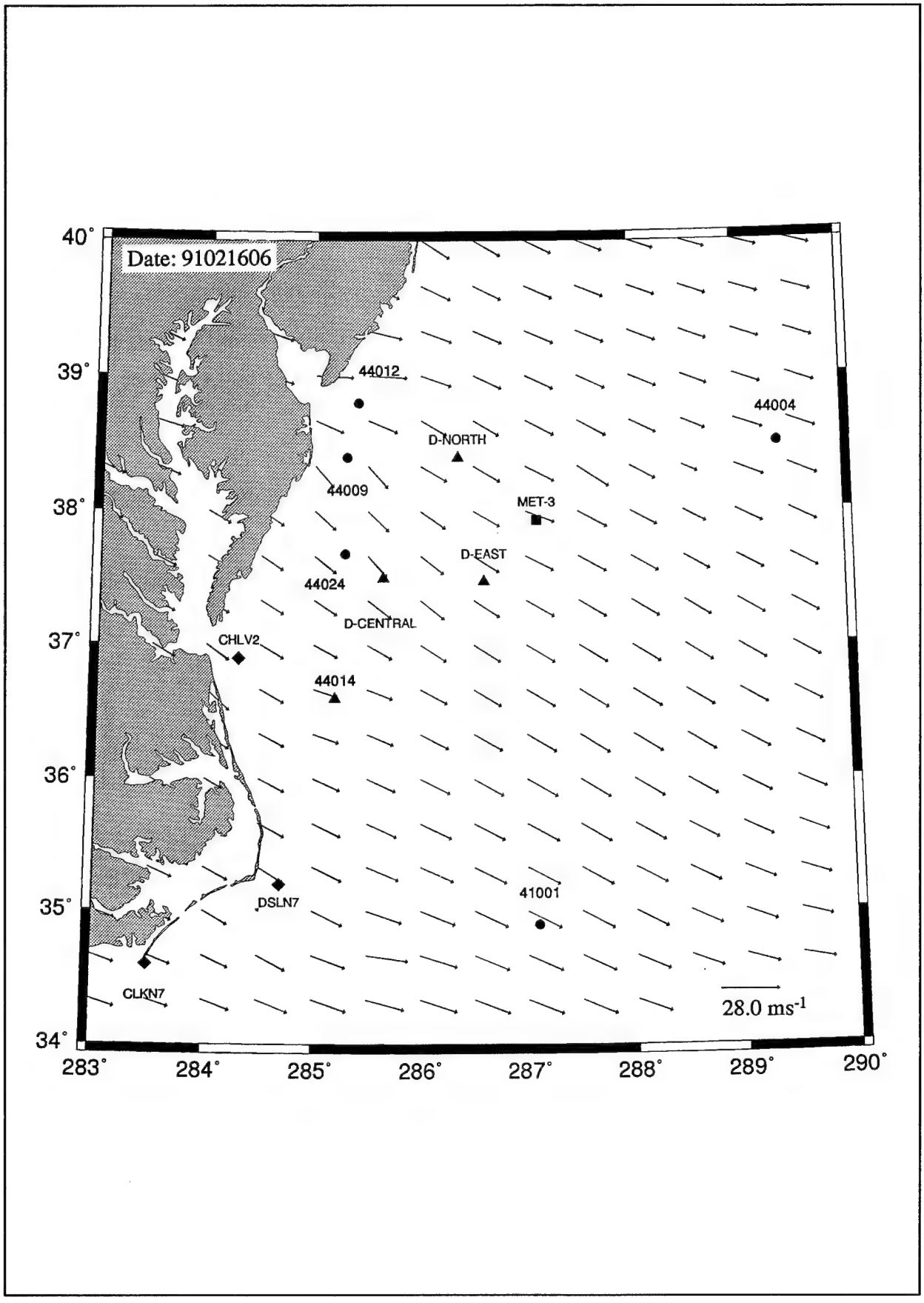
290°
44012
44004
D-NORTH
44009
MET-3
D-EAST
44024
D-CENTRAL
CHLV2
44014
DSLN7
41001
CLKN7
30.4 ms-1


Date: 91021606
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38°
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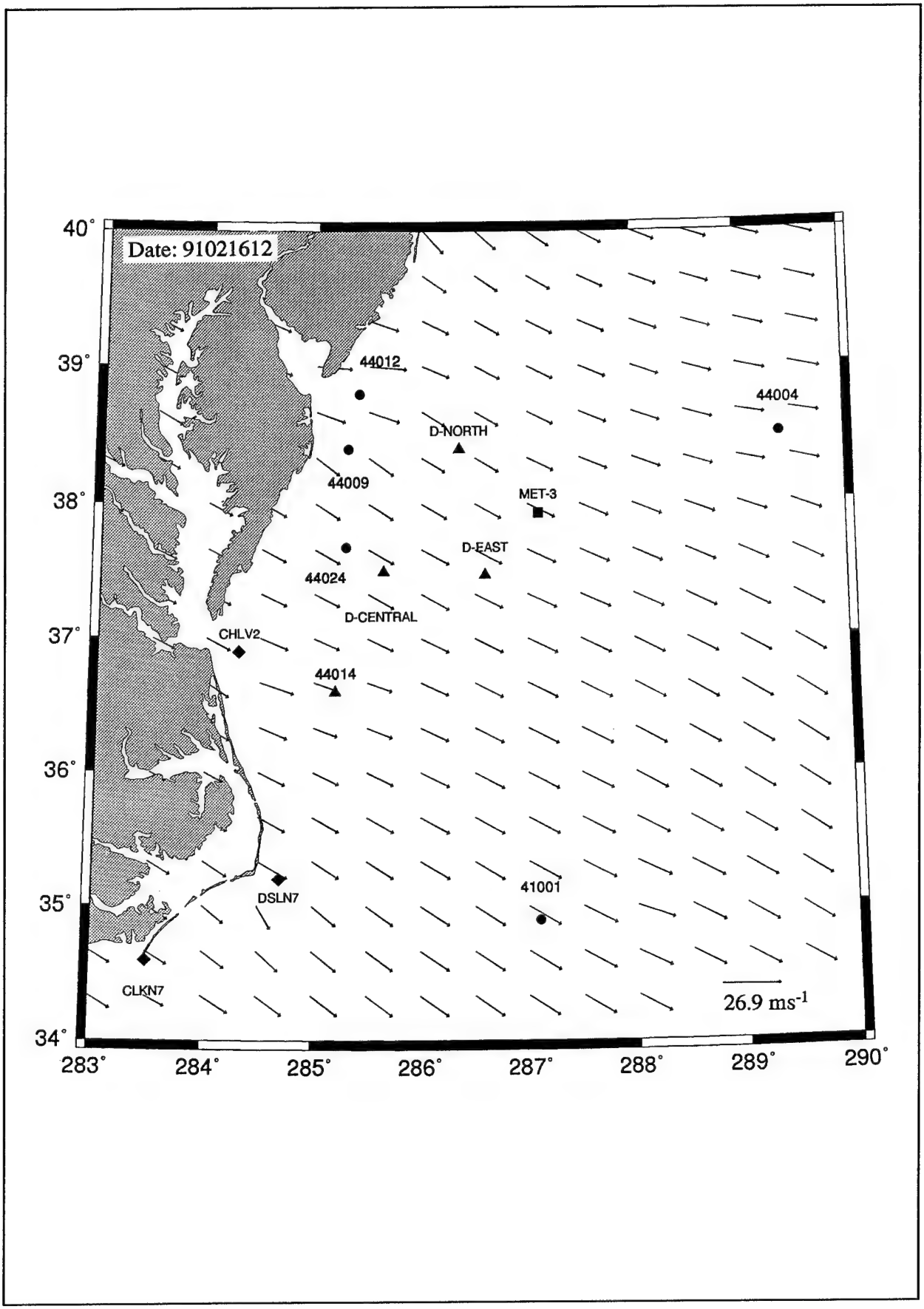
36°
35°
34°
283°
284°
285°
286°
287°
288°
289°
290°
44012
44004
D-NORTH
44009
MET-3
D-EAST
44024
D-CENTRAL
CHLV2
44014
DSLN7
41001
CLKN7
28.0 ms-1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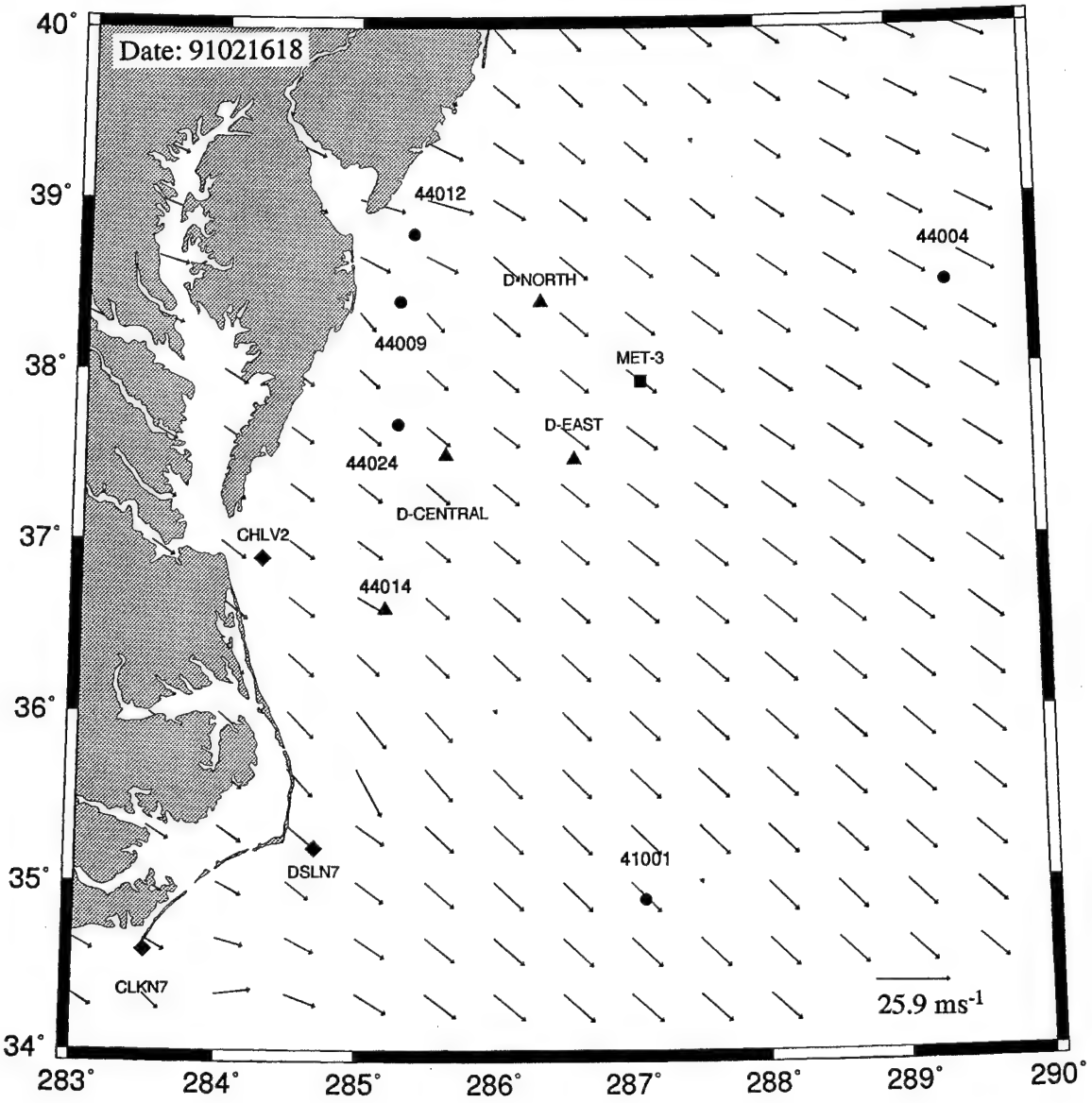
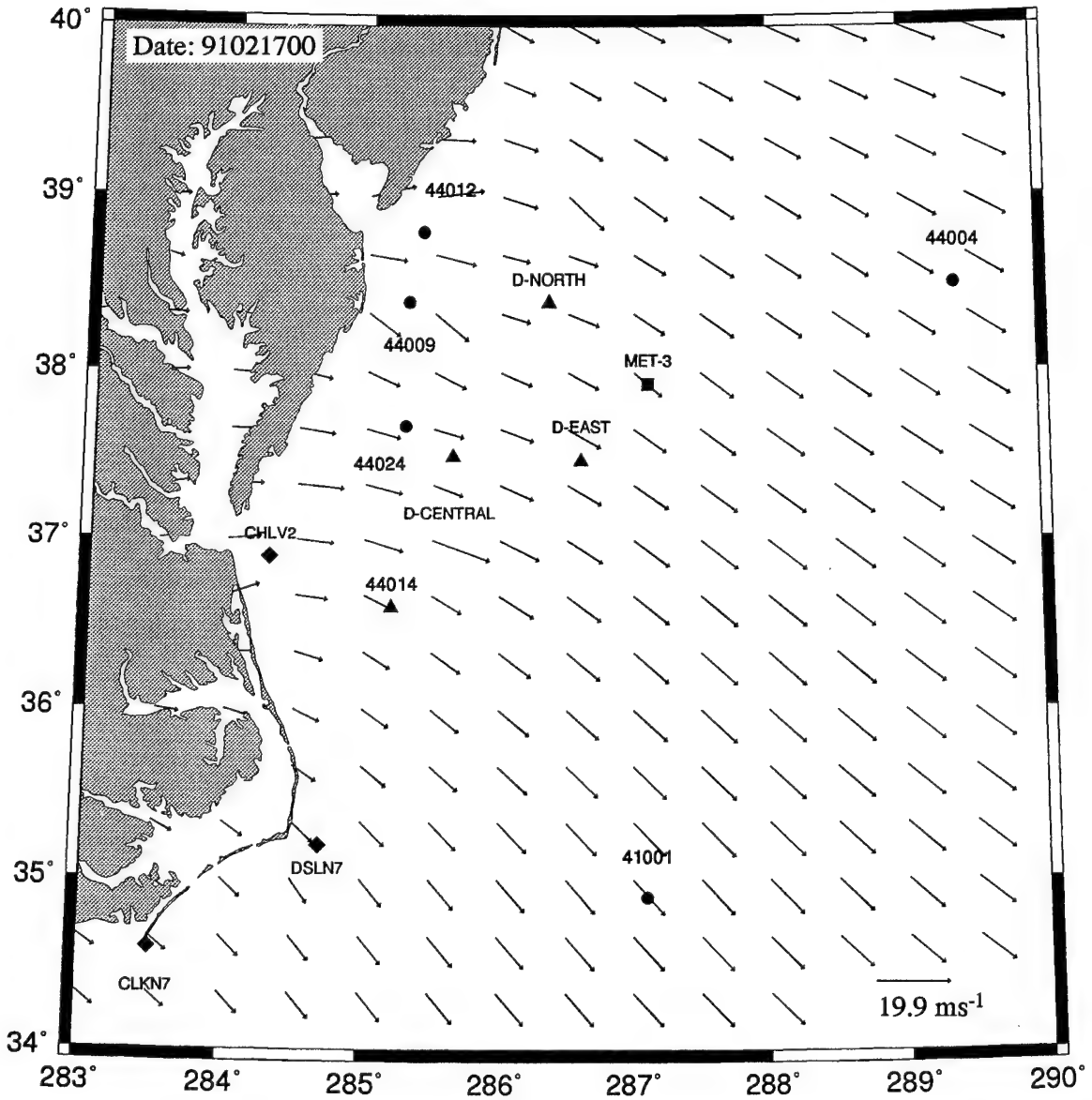
39°
38°
37°
36°
35°
34°
283°
284°
285°
286°
287°
288°
289°
290°
44012
44004
D-NORTH
44009
MET-3
D-EAST
44024
D-CENTRAL
CHLV2
44014
41001
DSLN7
CLKN7
26.9 ms-1


Date: 91021618
40°
39°
38°
37°
36°
35°
34°
283°
284°
285°
286°
287°
288°
289°
290°
44012
44004
D-NORTH
44009
MET-3
D-EAST
44024
D-CENTRAL
CHLV2
44014
41001
DSLN7
CLKN7
25.9 ms-1


Date: 91021700
40°
39°
38°
37°
36°
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34°
283°
284°
285°
286°
287°
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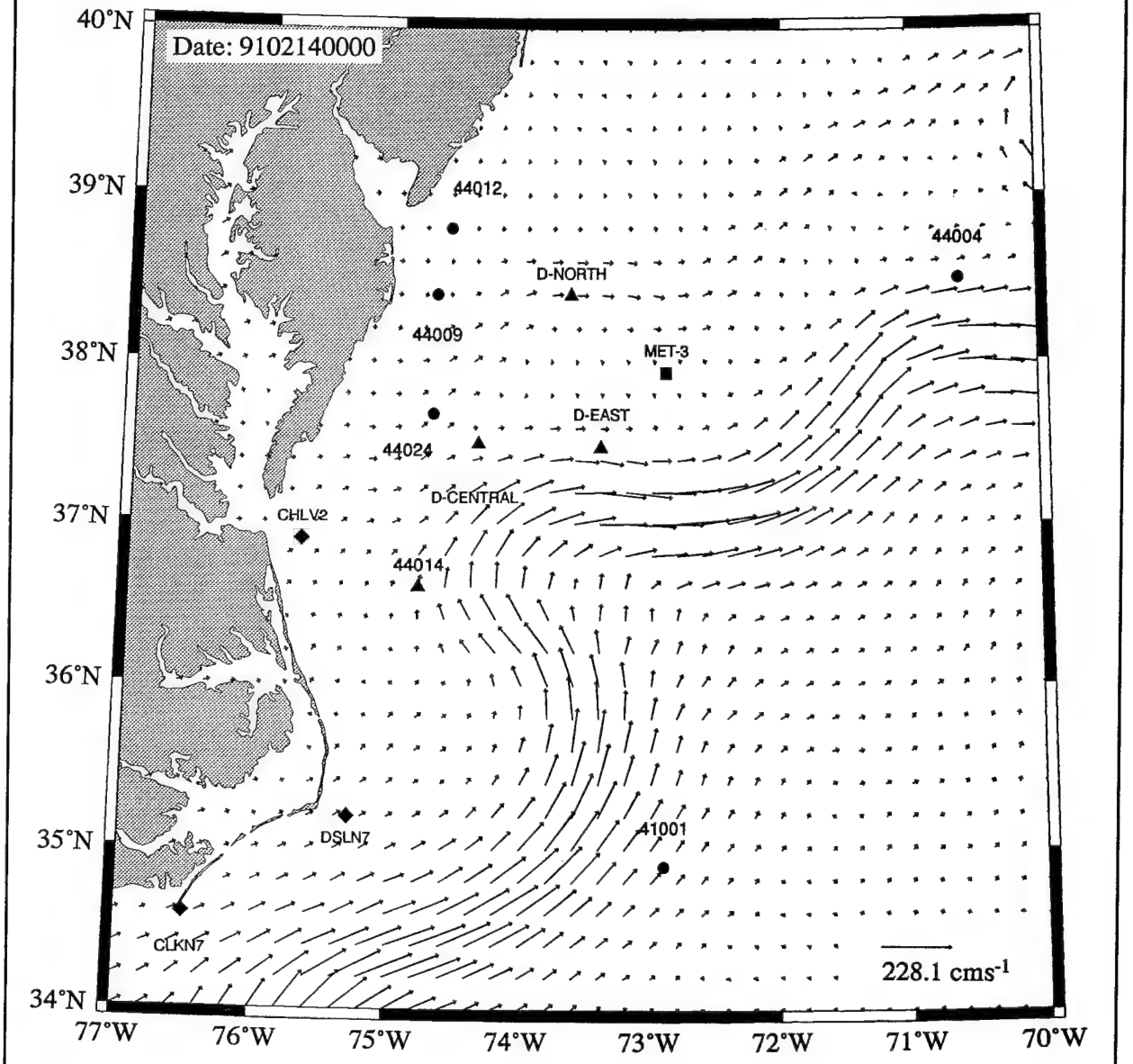
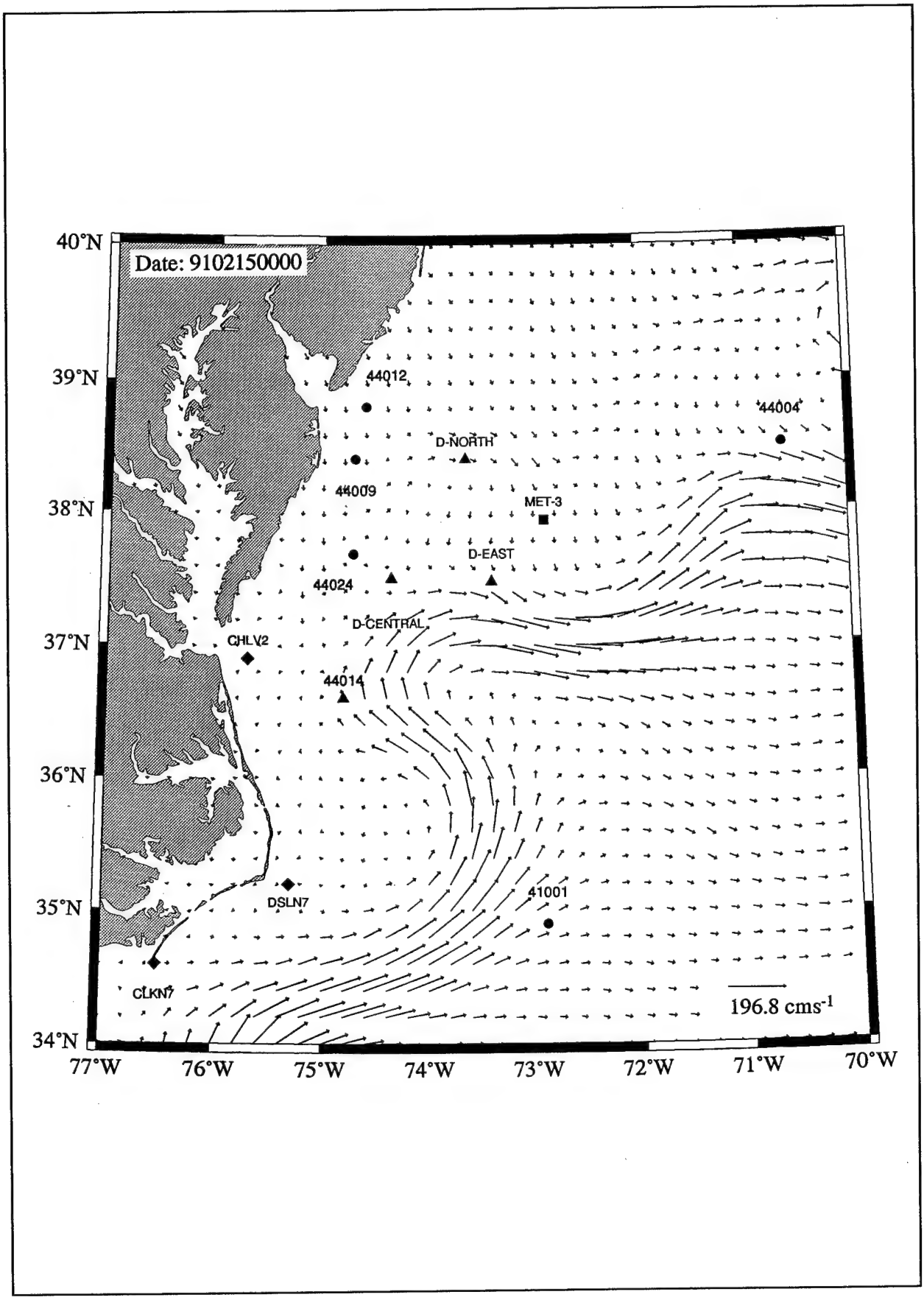
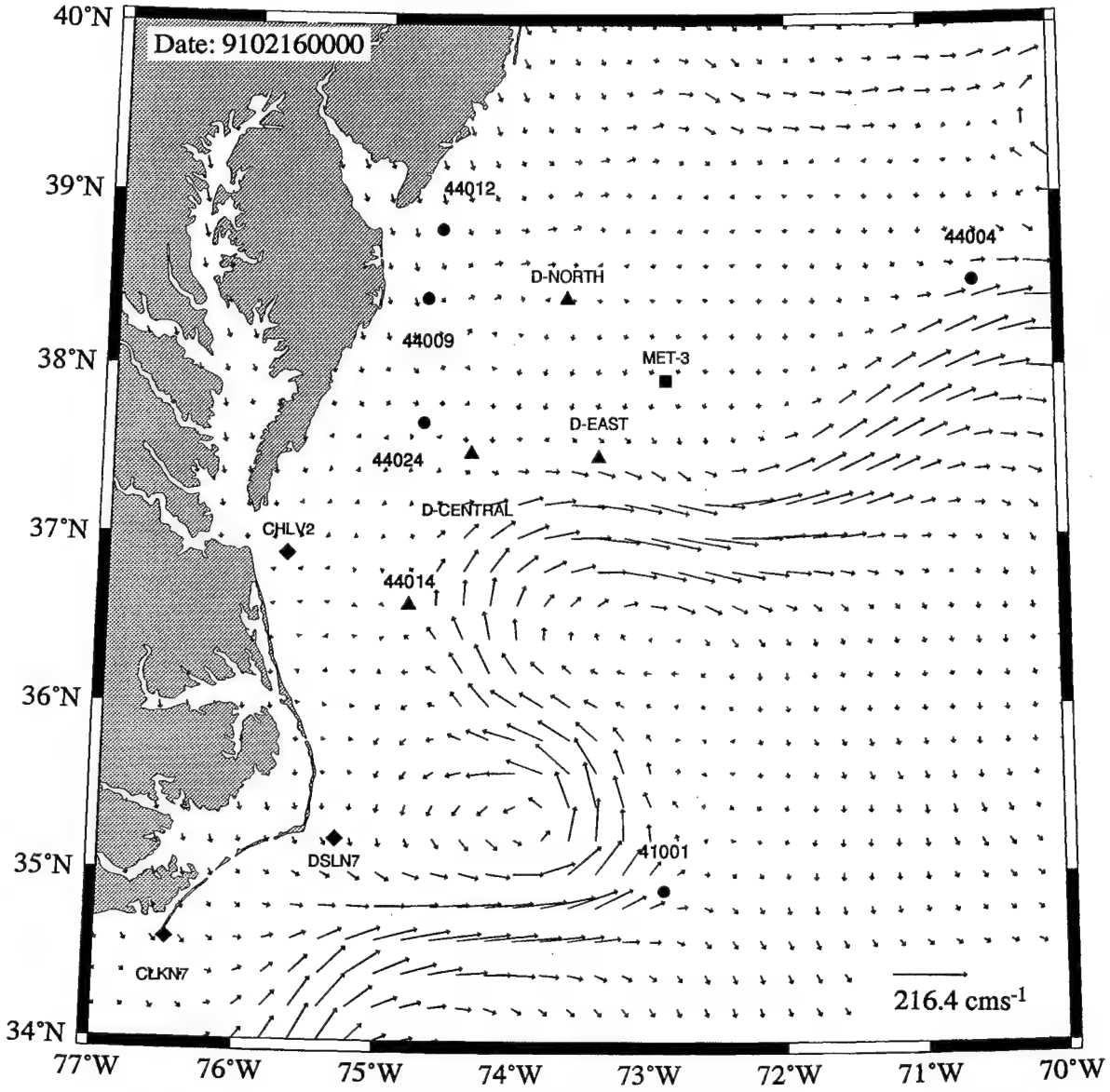
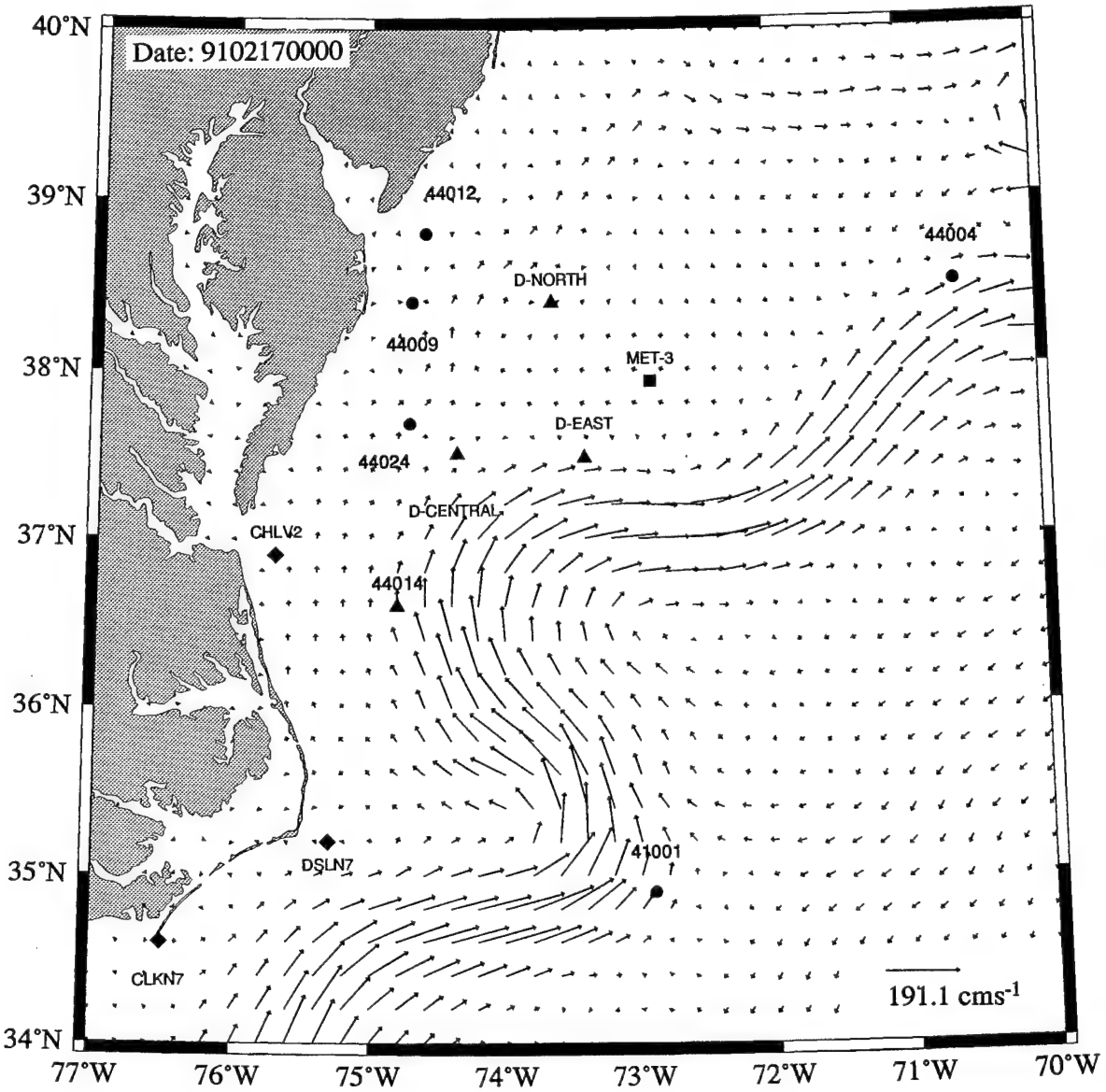
289°
290°
44012
44004
D-NORTH
44009
MET-3
D-EAST
44024
D-CENTRAL
CHLV2
44014
DSLN7
41001
CLKN7
19.9 ms-1

Appendix C
NOGUFS Current Fields, 14-16 February 1991


Date: 9102140000
40°N
39°N
38°N
37°N
36°N
35°N
34°N
77°W
76°W
75°W
74°W
73°W
72°W
71°W
70°W
44012
44004
D-NORTH
44009
MET-3
D-EAST
44024
D-CENTRAL
CHLV2
44014
DSLN7
41001
CLKN7
228.1 cms-1


Date: 9102150000
40°N
39°N
38°N
37°N
36°N
35°N
34°N
77°W
76°W
75°W
74°W
73°W
72°W
71°W
70°W
44012
44004
D-NORTH
44009
MET-3
D-EAST
44024
D-CENTRAL
CHLV2
44014
DSLN7
41001
CLKN7
196.8 cms-1


Date: 9102160000
40°N
39°N
38°N
37°N
36°N
35°N
34°N
77°W
76°W
75°W
74°W
73°W
72°W
71°W
70°W
44012
44004
D-NORTH
44009
MET-3
D-EAST
44024
D-CENTRAL
CHLV2
44014
DSLN7
41001
CLKN7
216.4 cms-1


Date: 9102170000
40°N
39°N
38°N
37°N
36°N
35°N
34°N
77°W
76°W
75°W
74°W
73°W
72°W
71°W
70°W
44012
44004
D-NORTH
44009
MET-3
D-EAST
44024
D-CENTRAL
CHLV2
44014
DSLN7
41001
CLKN7
191.1 cms-1

Appendix D
Buoy Spectra, 12, 14-16 February 1991

This appendix contains three-hourly directional spectra from the four SWADE directional wave buoys, viz., Discus-North, Discus-East, Discus-Center, and Buoy CERC. The time period covered is 14-16 February. This is the main data collection period for the ROWS for the St. Valentines wind/wave event.

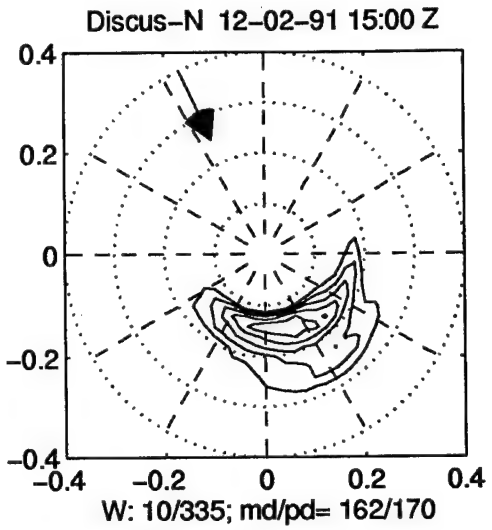
The directional wave energy spectra $E(f,\phi)$ in m^2/Hz/rad are plotted in polar coordinates with logarithmically spaced contours. The contour interval is 2.5 dB. The frequency rings are spaced 0.1 Hz; the highest frequency is 0.4 Hz.

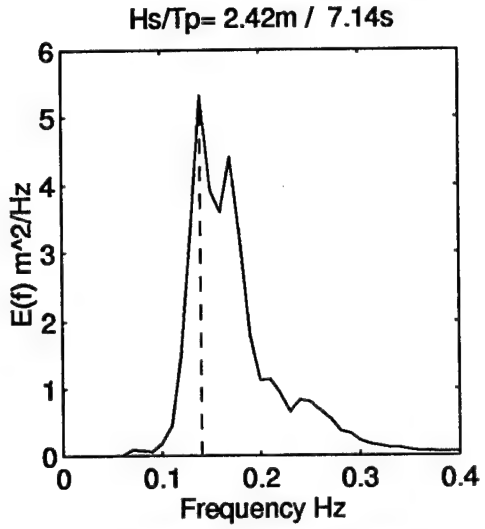
Below each directional spectrum plot are the buoy wind speed (in ms^{-1}) and direction (in degrees true according to meteorological convention) and the peak and mean wave directions (directions to). Peak directions are approximate since they are only bin values.

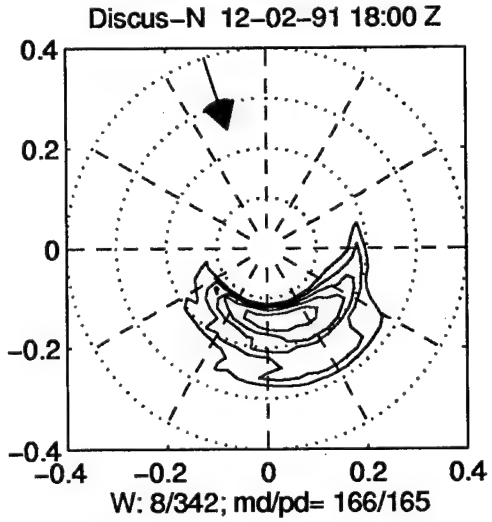
The nondirectional spectrum is given to the right of each directional spectrum. At the top of the nondirectional spectrum plot are the significant wave height (*Hs*) and the peak period (*Tp*). Note that the *Tp* are bin values, and thus imprecise.

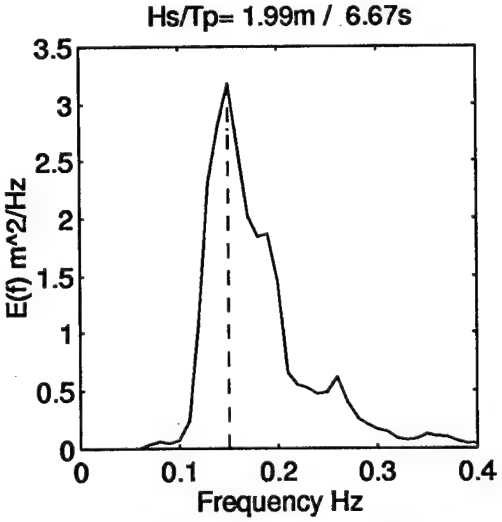
Appendix D1: 12 February 1991

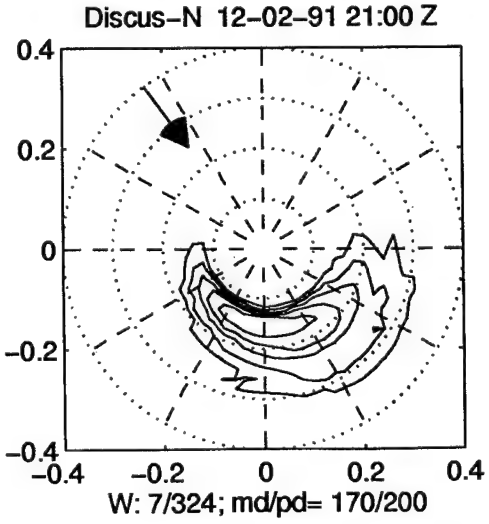
Discus-N
Discus-E
Discus-C
Buoy-CR

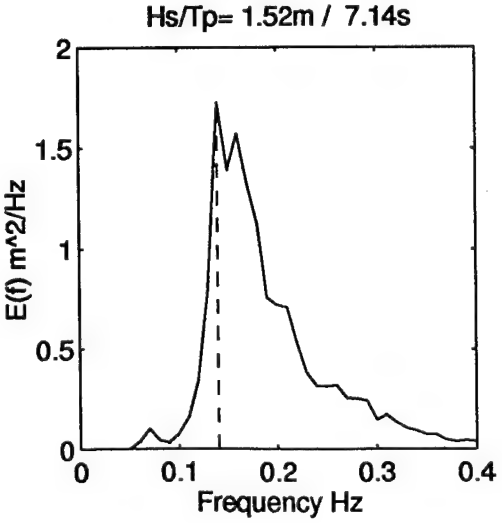

Discus-N 12-02-91 15:00 Z
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
W: 10/335; md/pd= 162/170

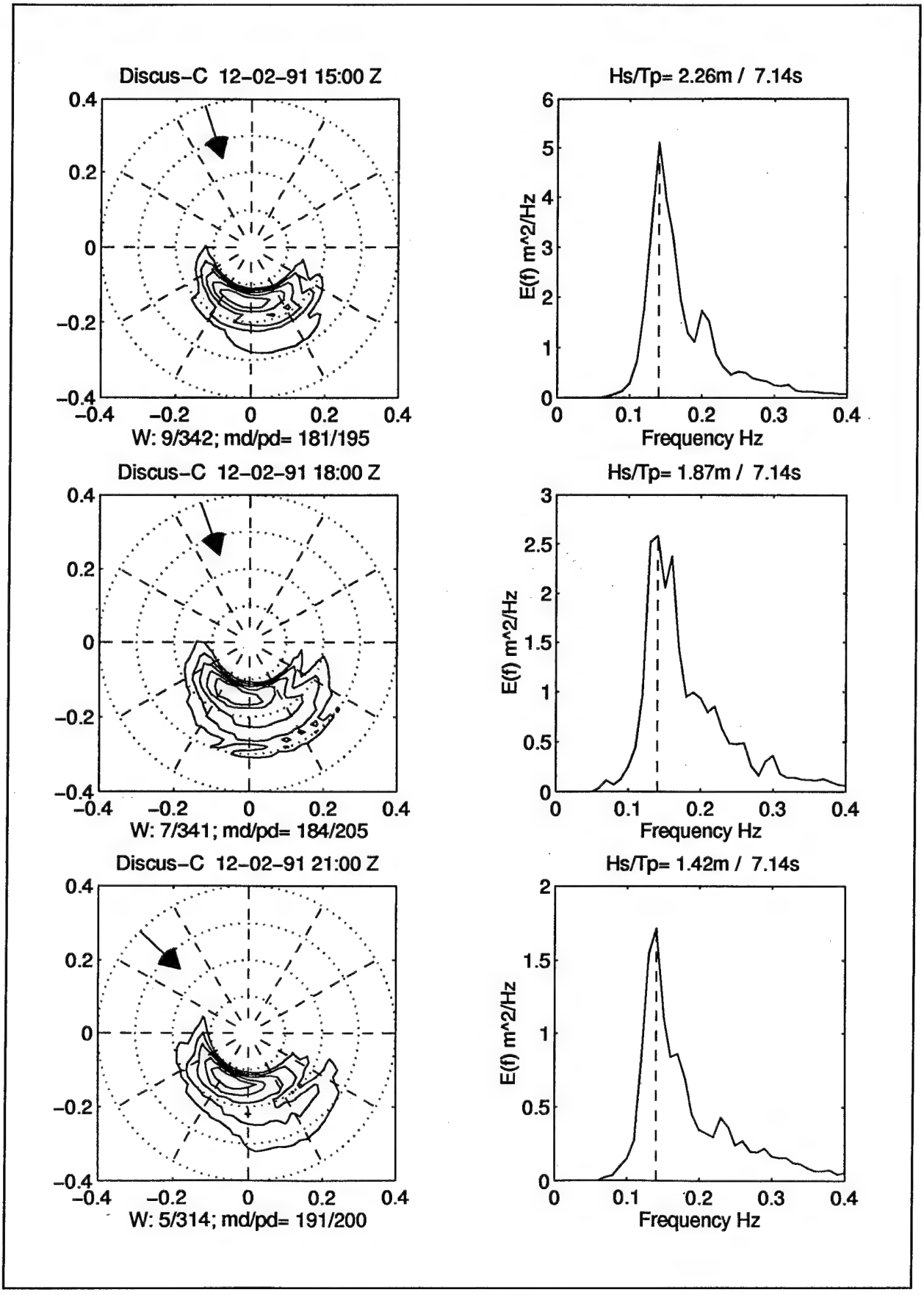

Hs/Tp= 2.42m / 7.14s
E(f) m^2/Hz
0 1 2 3 4 5 6
0 0.1 0.2 0.3 0.4
Frequency Hz

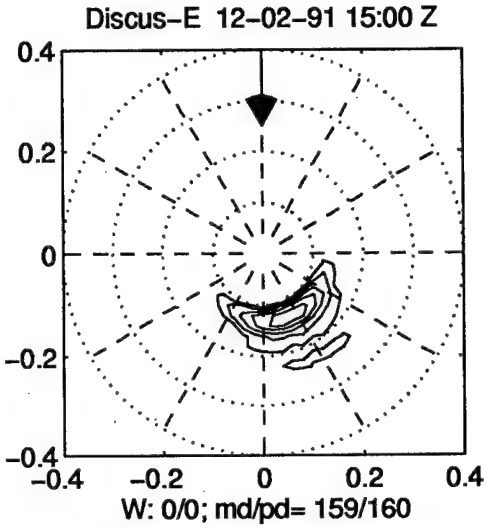

Discus-N 12-02-91 18:00 Z
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
W: 8/342; md/pd= 166/165

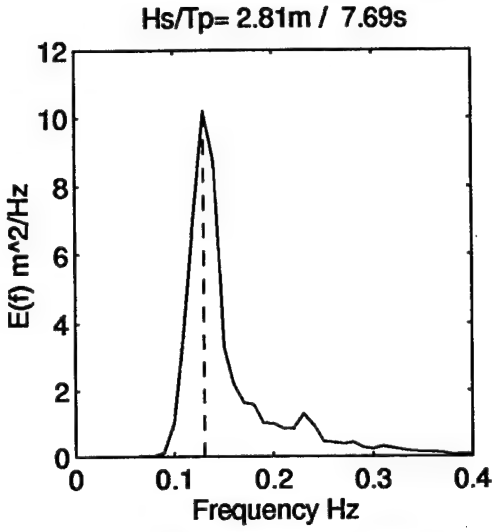

Hs/Tp= 1.99m / 6.67s
E(f) m^2/Hz
0 0.5 1 1.5 2 2.5 3 3.5
0 0.1 0.2 0.3 0.4
Frequency Hz

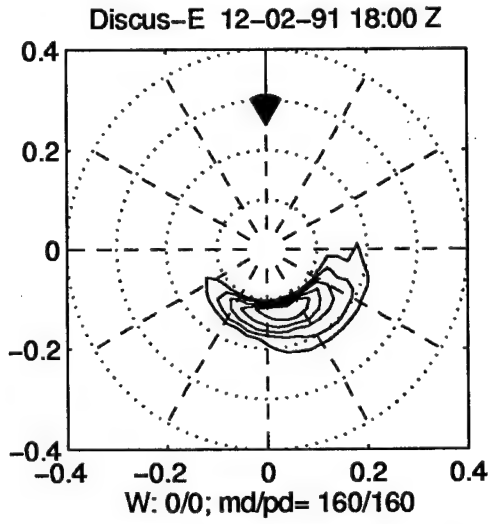

Discus-N 12-02-91 21:00 Z
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
W: 7/324; md/pd= 170/200

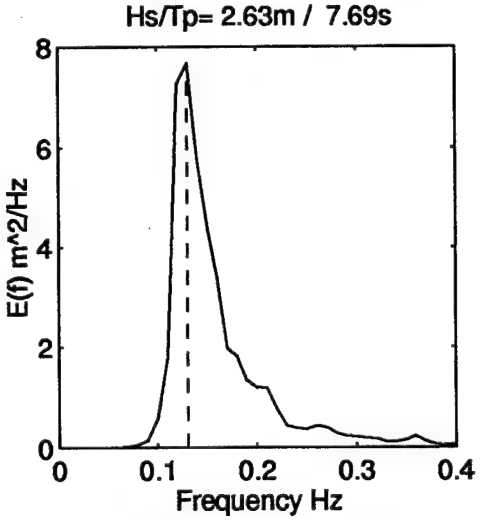

Hs/Tp= 1.52m / 7.14s
E(f) m^2/Hz
0 0.5 1 1.5 2
0 0.1 0.2 0.3 0.4
Frequency Hz

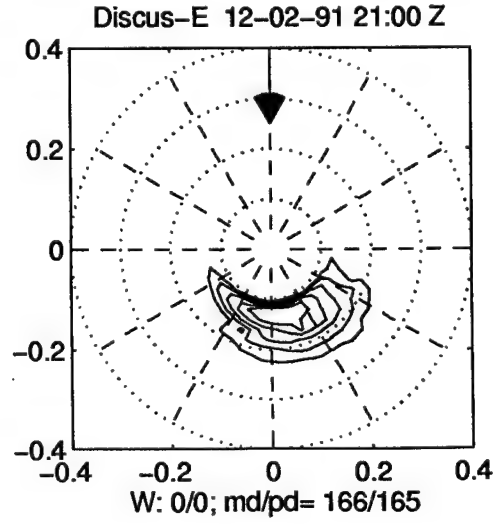

Discus-C 12-02-91 15:00 Z
W: 9/342; md/pd= 181/195
Hs/Tp= 2.26m / 7.14s
E(f) m^2/Hz
Frequency Hz
Discus-C 12-02-91 18:00 Z
W: 7/341; md/pd= 184/205
Hs/Tp= 1.87m / 7.14s
E(f) m^2/Hz
Frequency Hz
Discus-C 12-02-91 21:00 Z
W: 5/314; md/pd= 191/200
Hs/Tp= 1.42m / 7.14s
E(f) m^2/Hz
Frequency Hz

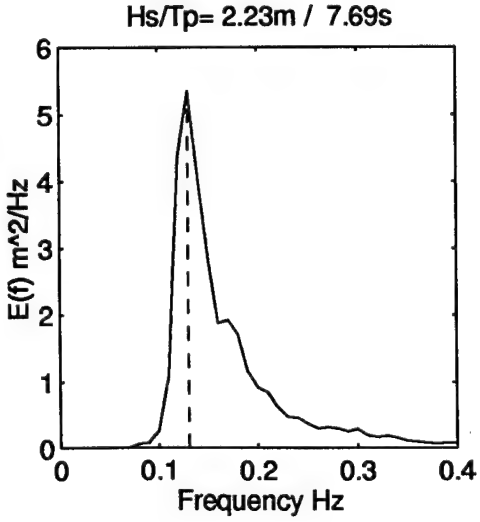

Discus-E 12-02-91 15:00 Z
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
W: 0/0; md/pd= 159/160

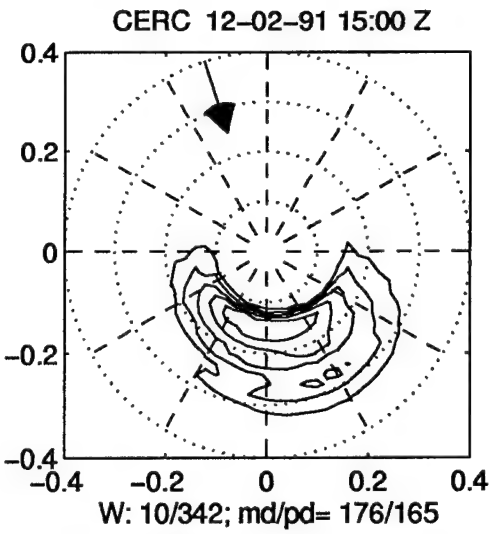

Hs/Tp= 2.81m / 7.69s
E(f) m^2/Hz
12
10
8
6
4
2
0
0 0.1 0.2 0.3 0.4
Frequency Hz

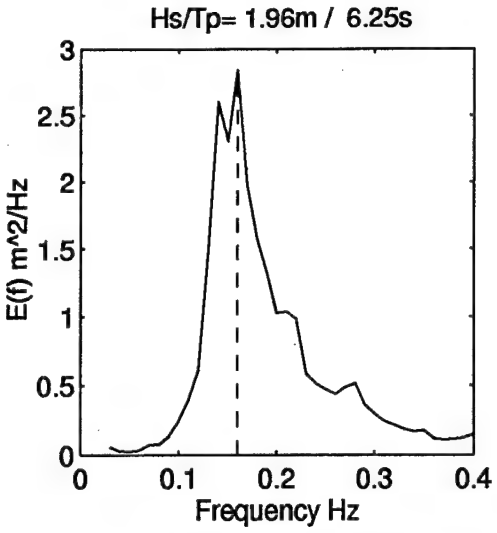

Discus-E 12-02-91 18:00 Z
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
W: 0/0; md/pd= 160/160

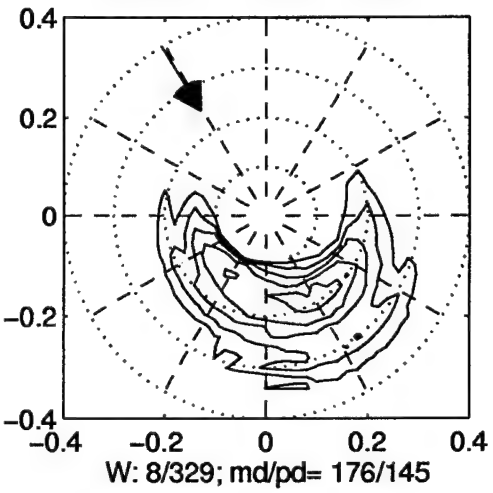

Hs/Tp= 2.63m / 7.69s
E(f) m^2/Hz
8
6
4
2
0
0 0.1 0.2 0.3 0.4
Frequency Hz

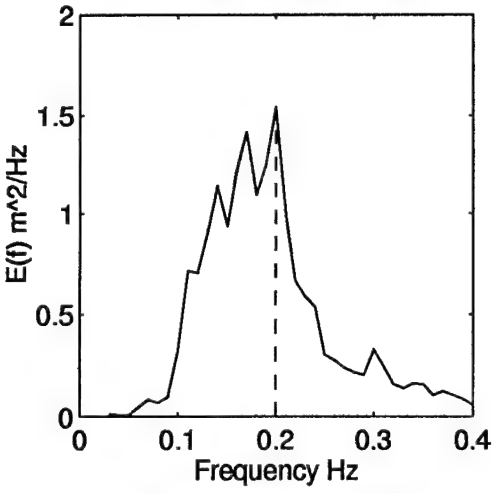

Discus-E 12-02-91 21:00 Z
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
W: 0/0; md/pd= 166/165

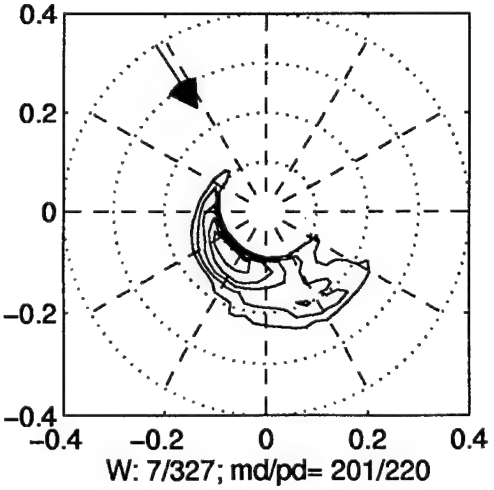

Hs/Tp= 2.23m / 7.69s
E(f) m^2/Hz
6
5
4
3
2
1
0
0 0.1 0.2 0.3 0.4
Frequency Hz

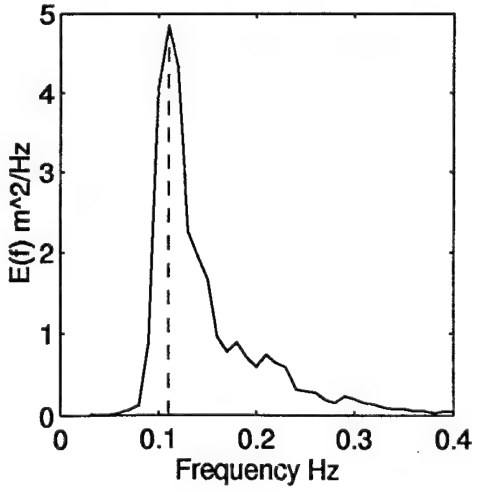

CERC 12-02-91 15:00 Z
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
W: 10/342; md/pd= 176/165


Hs/Tp= 1.96m / 6.25s
E(f) m^2/Hz
3
2.5
2
1.5
1
0.5
0
0 0.1 0.2 0.3 0.4
Frequency Hz

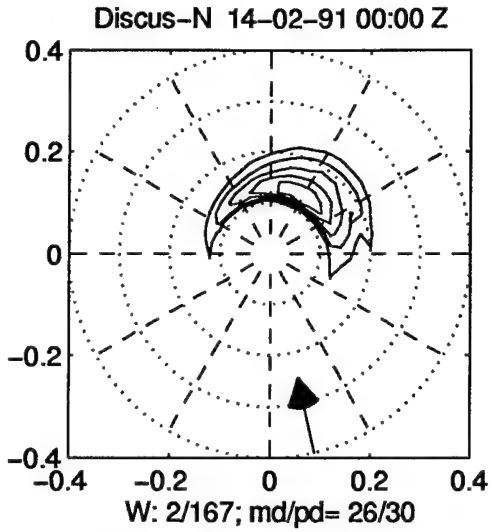

CERC 12-02-91 18:00 Z
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
W: 8/329; md/pd= 176/145

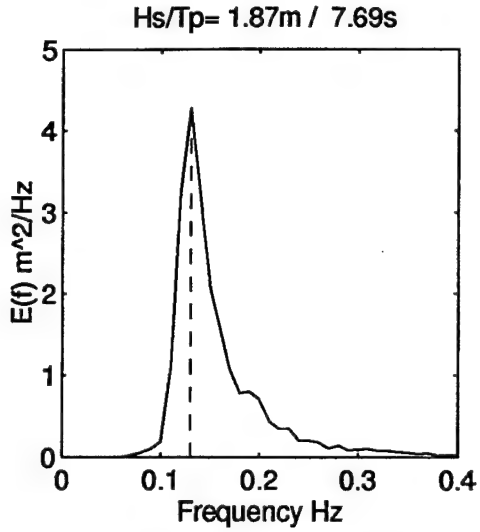

Hs/Tp= 1.66m / 5.00s
E(f) m^2/Hz
2
1.5
1
0.5
0
0 0.1 0.2 0.3 0.4
Frequency Hz

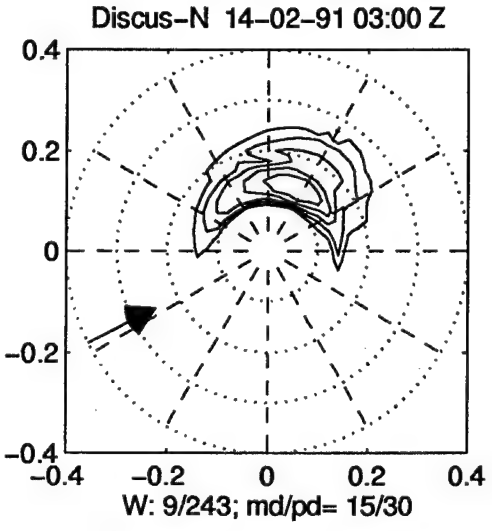

CERC 12-02-91 21:00 Z
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
W: 7/327; md/pd= 201/220

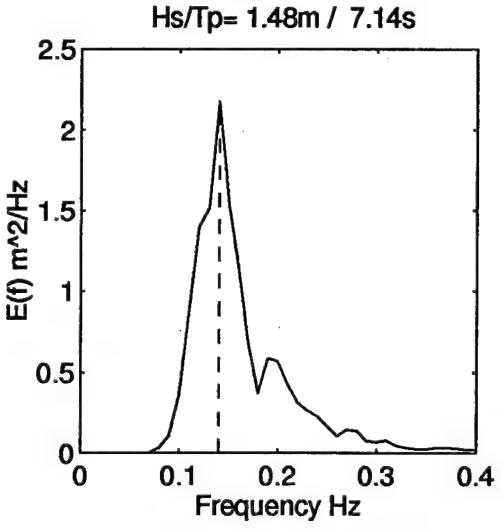

Hs/Tp= 2.14m / 9.09s
E(f) m^2/Hz
5
4
3
2
1
0
0 0.1 0.2 0.3 0.4
Frequency Hz

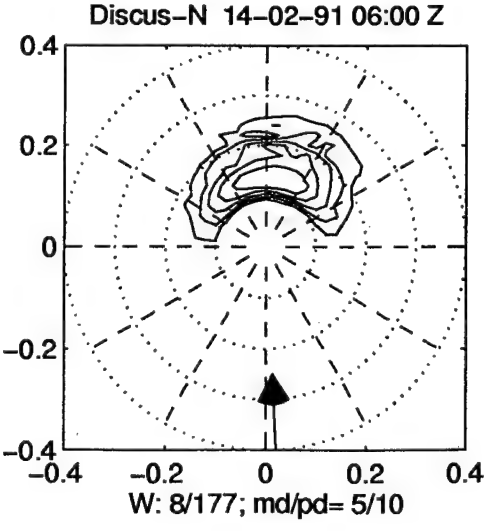
Appendix D2: Discus-North
14-16 February 1991

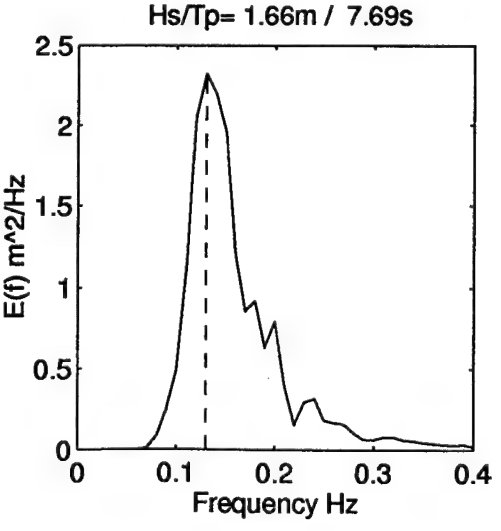

Discus-N 14-02-91 00:00 Z
W: 2/167; md/pd= 26/30

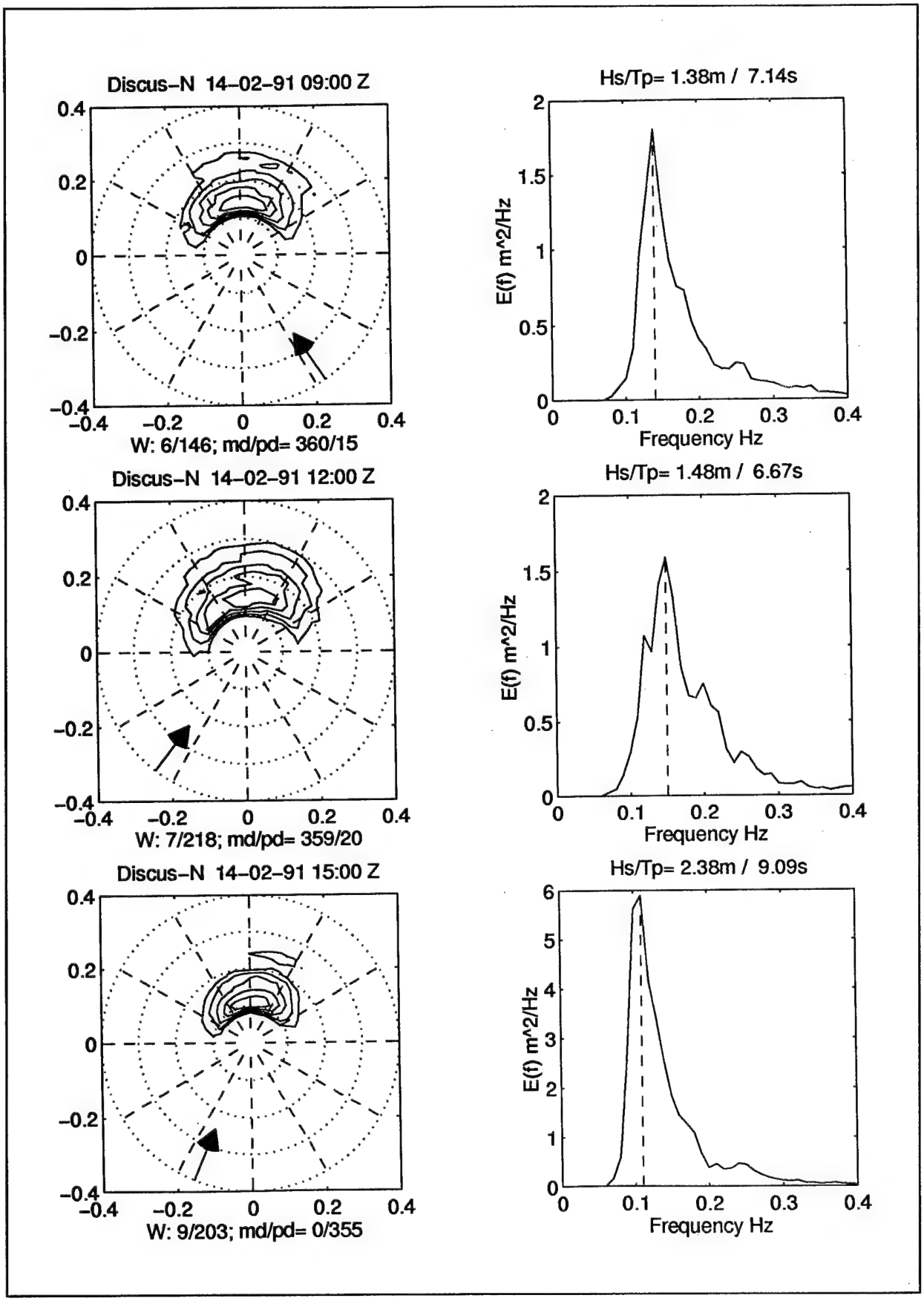

Hs/Tp= 1.87m / 7.69s
E(f) m^2/Hz
Frequency Hz

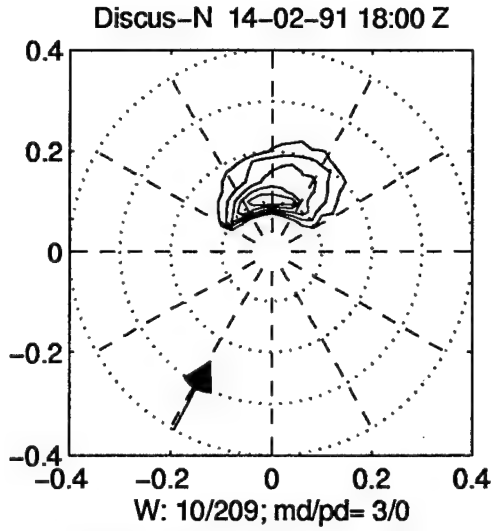

Discus-N 14-02-91 03:00 Z
W: 9/243; md/pd= 15/30

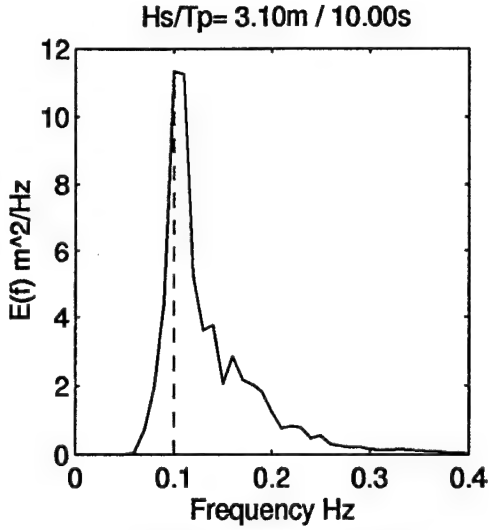

Hs/Tp= 1.48m / 7.14s
E(f) m^2/Hz
Frequency Hz

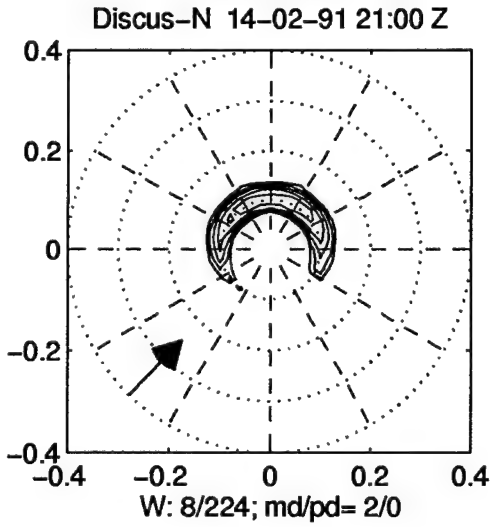

Discus-N 14-02-91 06:00 Z
W: 8/177; md/pd= 5/10

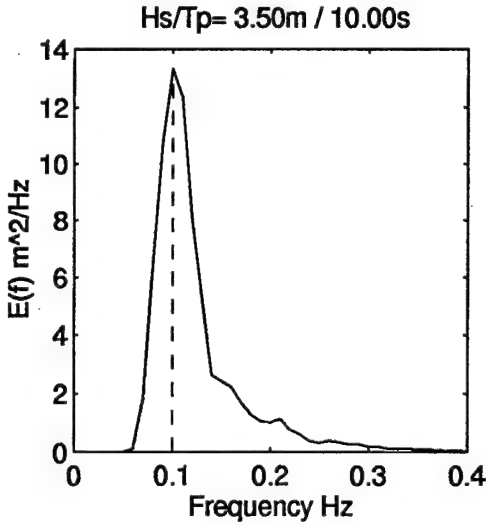

Hs/Tp= 1.66m / 7.69s
E(f) m^2/Hz
Frequency Hz

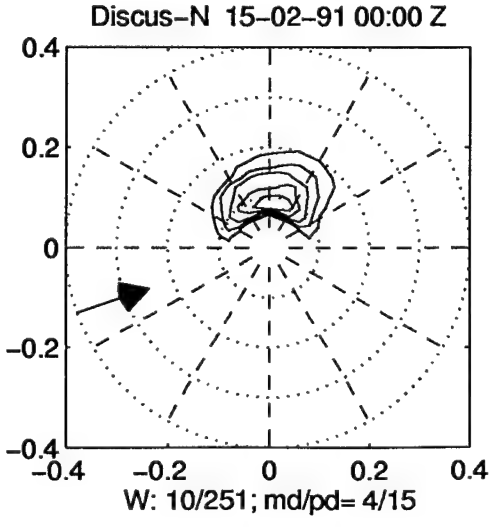

Discus-N 14-02-91 09:00 Z
W: 6/146; md/pd= 360/15
Hs/Tp= 1.38m / 7.14s
E(f) m^2/Hz
Frequency Hz
Discus-N 14-02-91 12:00 Z
W: 7/218; md/pd= 359/20
Hs/Tp= 1.48m / 6.67s
E(f) m^2/Hz
Frequency Hz
Discus-N 14-02-91 15:00 Z
W: 9/203; md/pd= 0/355
Hs/Tp= 2.38m / 9.09s
E(f) m^2/Hz
Frequency Hz

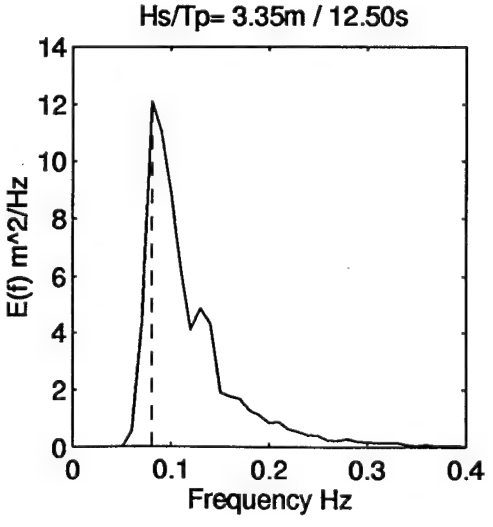

Discus-N 14-02-91 18:00 Z
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
W: 10/209; md/pd= 3/0

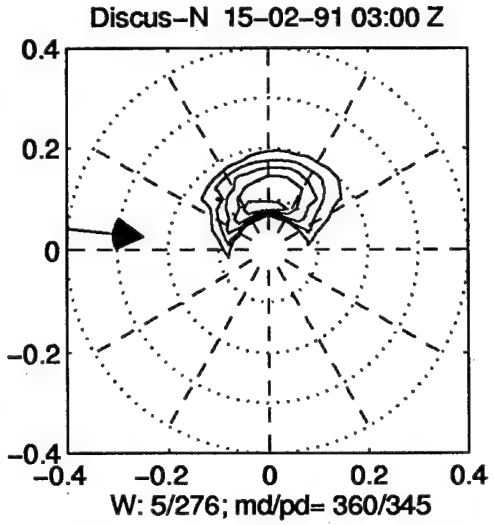

Hs/Tp= 3.10m / 10.00s
E(f) m^2/Hz
12
10
8
6
4
2
0
0 0.1 0.2 0.3 0.4
Frequency Hz

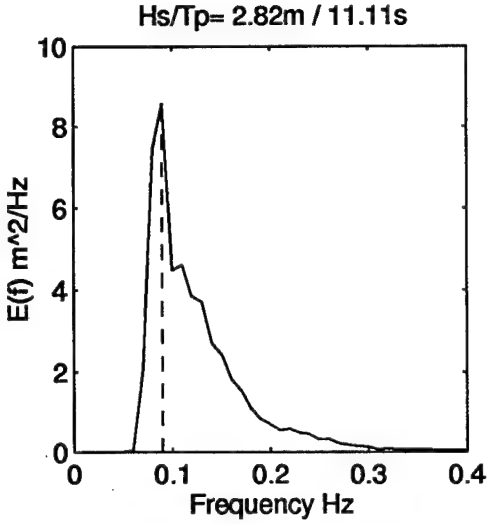

Discus-N 14-02-91 21:00 Z
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
W: 8/224; md/pd= 2/0

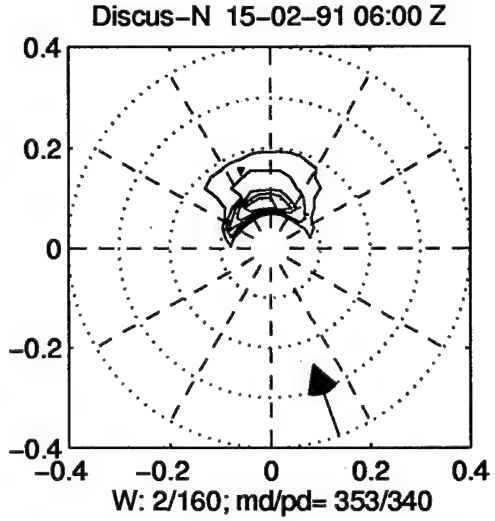

Hs/Tp= 3.50m / 10.00s
E(f) m^2/Hz
14
12
10
8
6
4
2
0
0 0.1 0.2 0.3 0.4
Frequency Hz

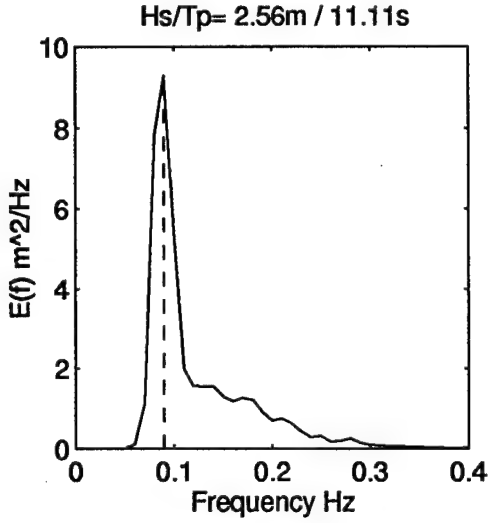

Discus-N 15-02-91 00:00 Z
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
W: 10/251; md/pd= 4/15

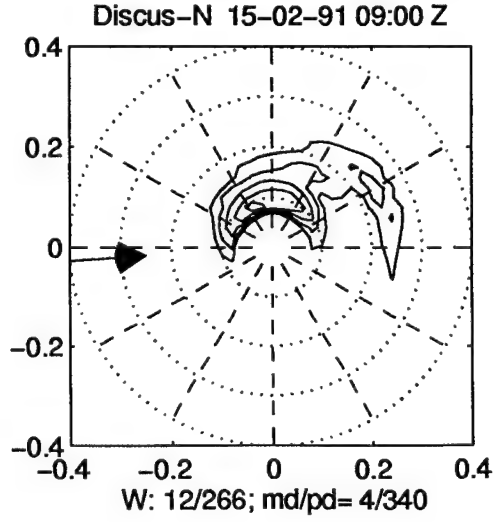

Hs/Tp= 3.35m / 12.50s
E(f) m^2/Hz
14
12
10
8
6
4
2
0
0 0.1 0.2 0.3 0.4
Frequency Hz

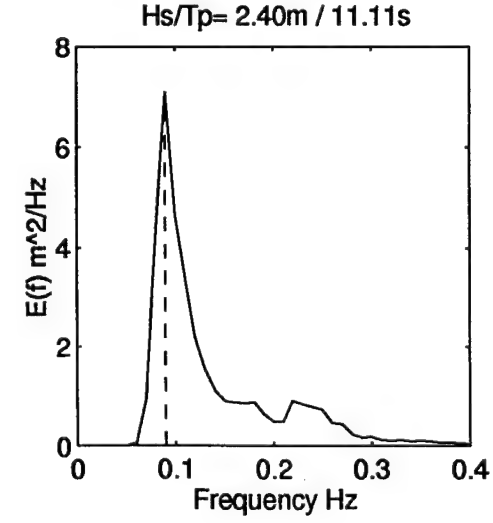

Discus-N 15-02-91 03:00 Z
W: 5/276; md/pd= 360/345

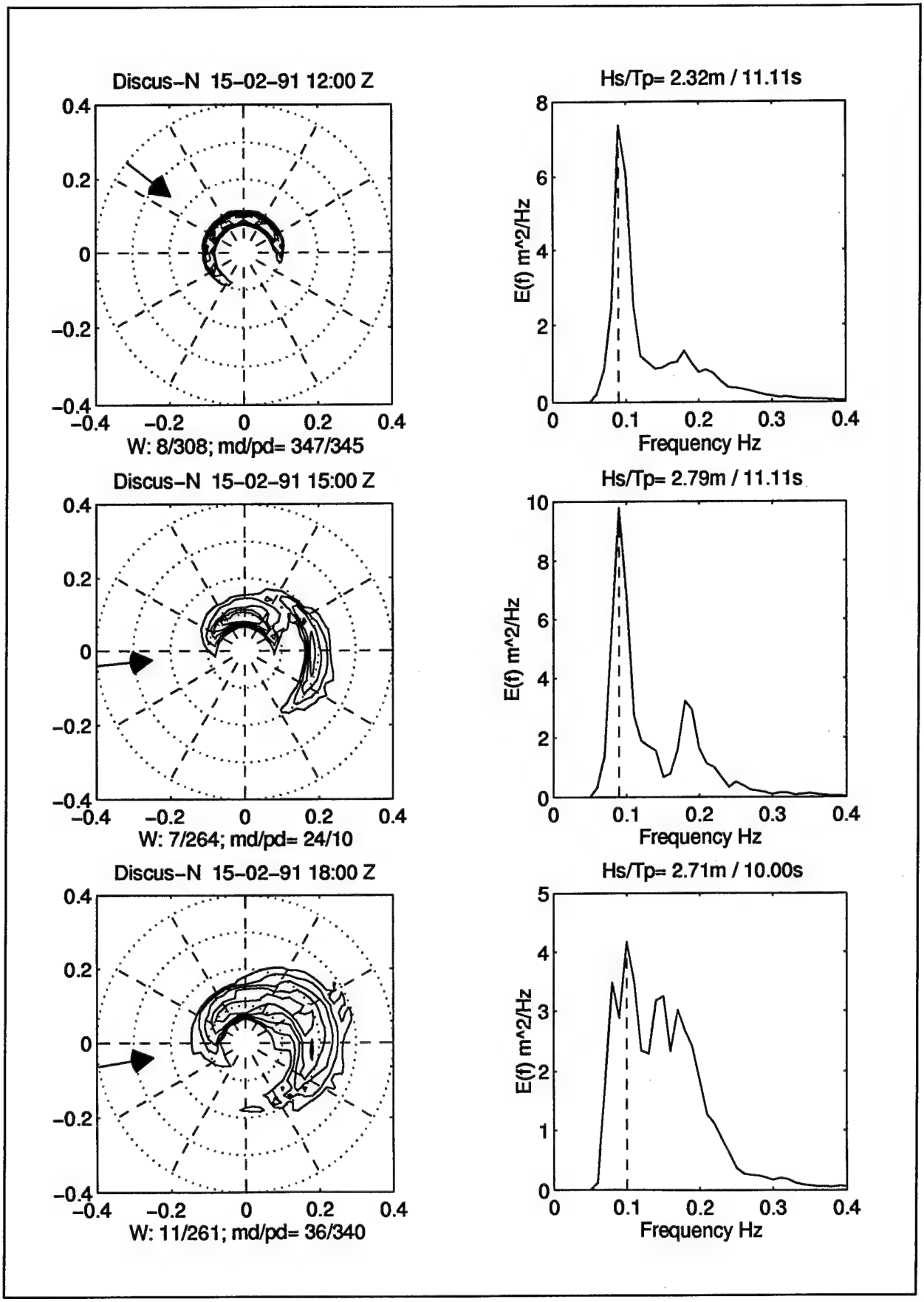

Hs/Tp= 2.82m / 11.11s
E(f) m^2/Hz
Frequency Hz

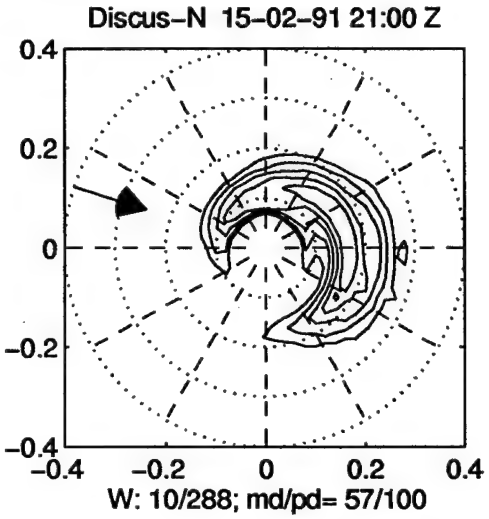

Discus-N 15-02-91 06:00 Z
W: 2/160; md/pd= 353/340

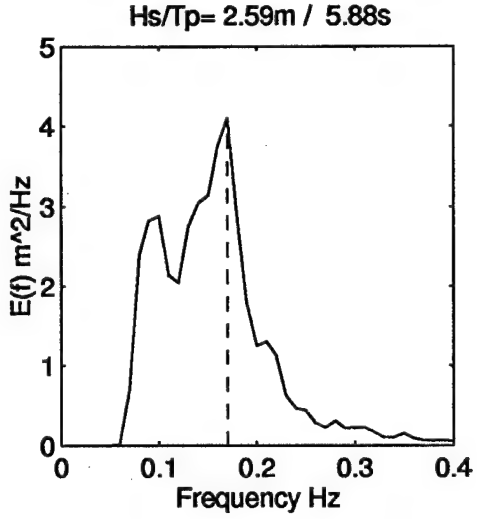

Hs/Tp= 2.56m / 11.11s
E(f) m^2/Hz
Frequency Hz

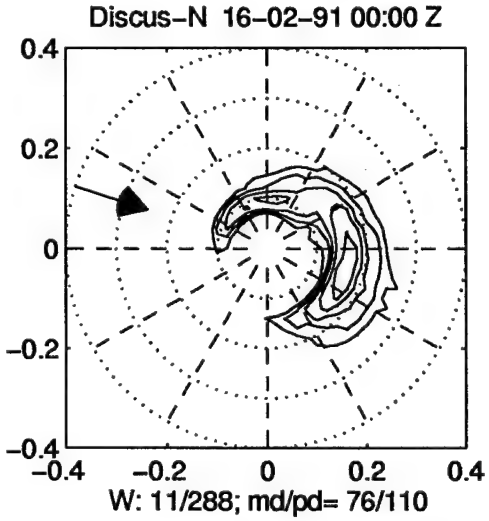

Discus-N 15-02-91 09:00 Z
W: 12/266; md/pd= 4/340

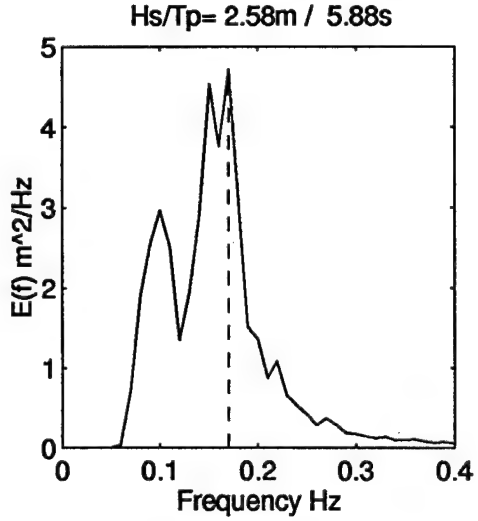

Hs/Tp= 2.40m / 11.11s
E(f) m^2/Hz
Frequency Hz


Discus-N 15-02-91 12:00 Z
W: 8/308; md/pd= 347/345
Hs/Tp= 2.32m / 11.11s
E(f) m^2/Hz
Frequency Hz
Discus-N 15-02-91 15:00 Z
W: 7/264; md/pd= 24/10
Hs/Tp= 2.79m / 11.11s
E(f) m^2/Hz
Frequency Hz
Discus-N 15-02-91 18:00 Z
W: 11/261; md/pd= 36/340
Hs/Tp= 2.71m / 10.00s
E(f) m^2/Hz
Frequency Hz

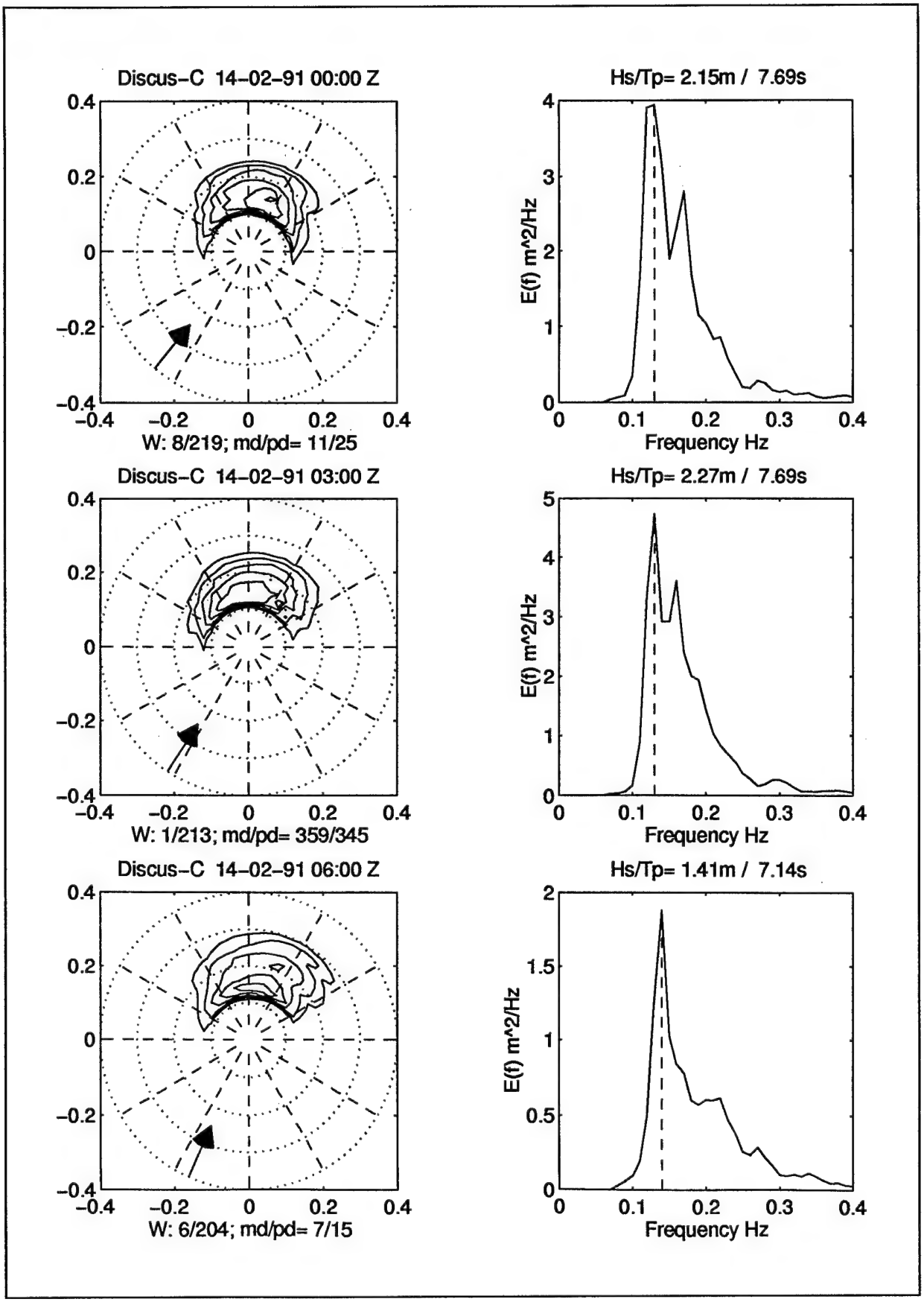

Discus-N 15-02-91 21:00 Z
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
W: 10/288; md/pd= 57/100

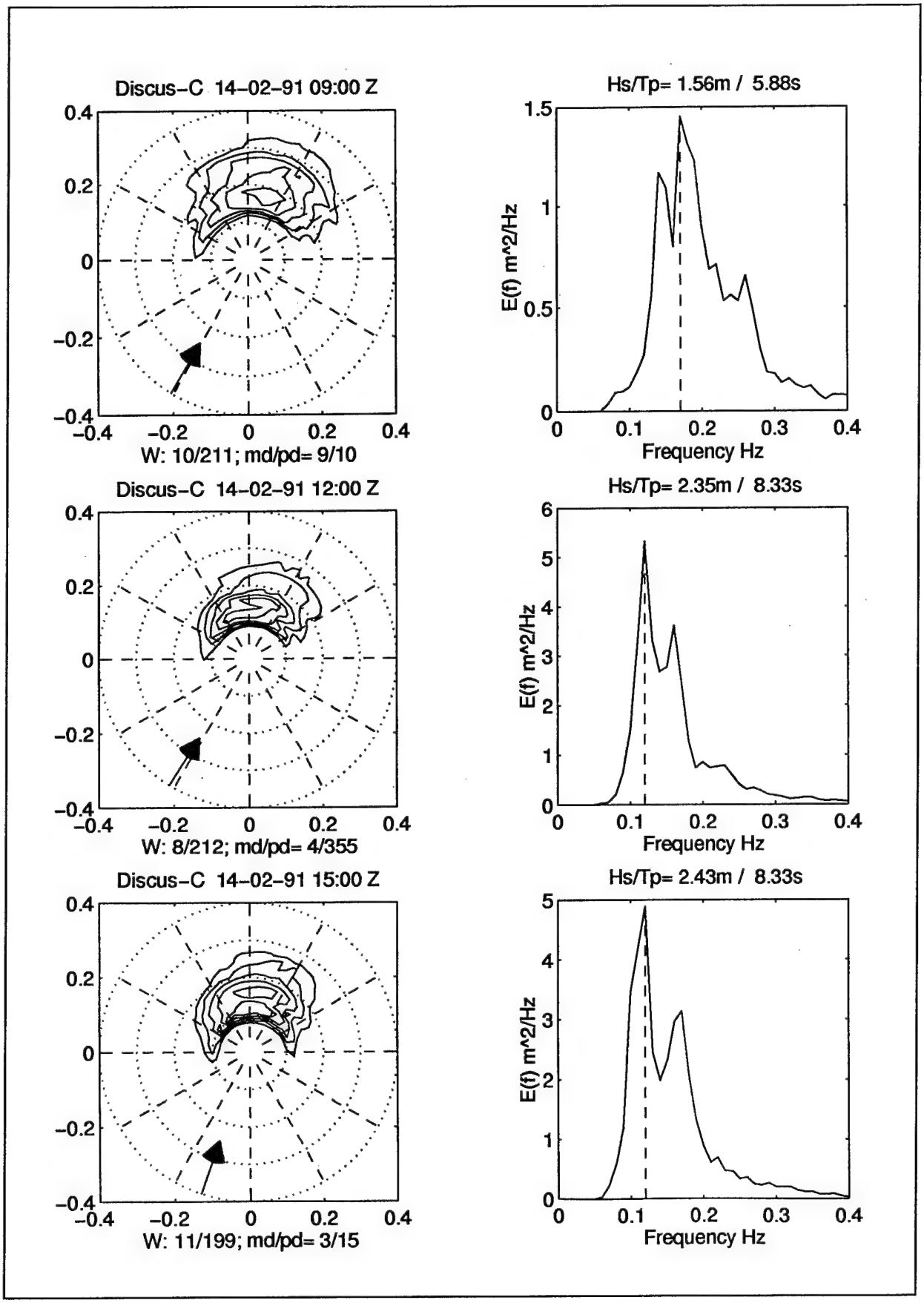

Hs/Tp= 2.59m / 5.88s
E(f) m^2/Hz
5
4
3
2
1
0
0 0.1 0.2 0.3 0.4
Frequency Hz

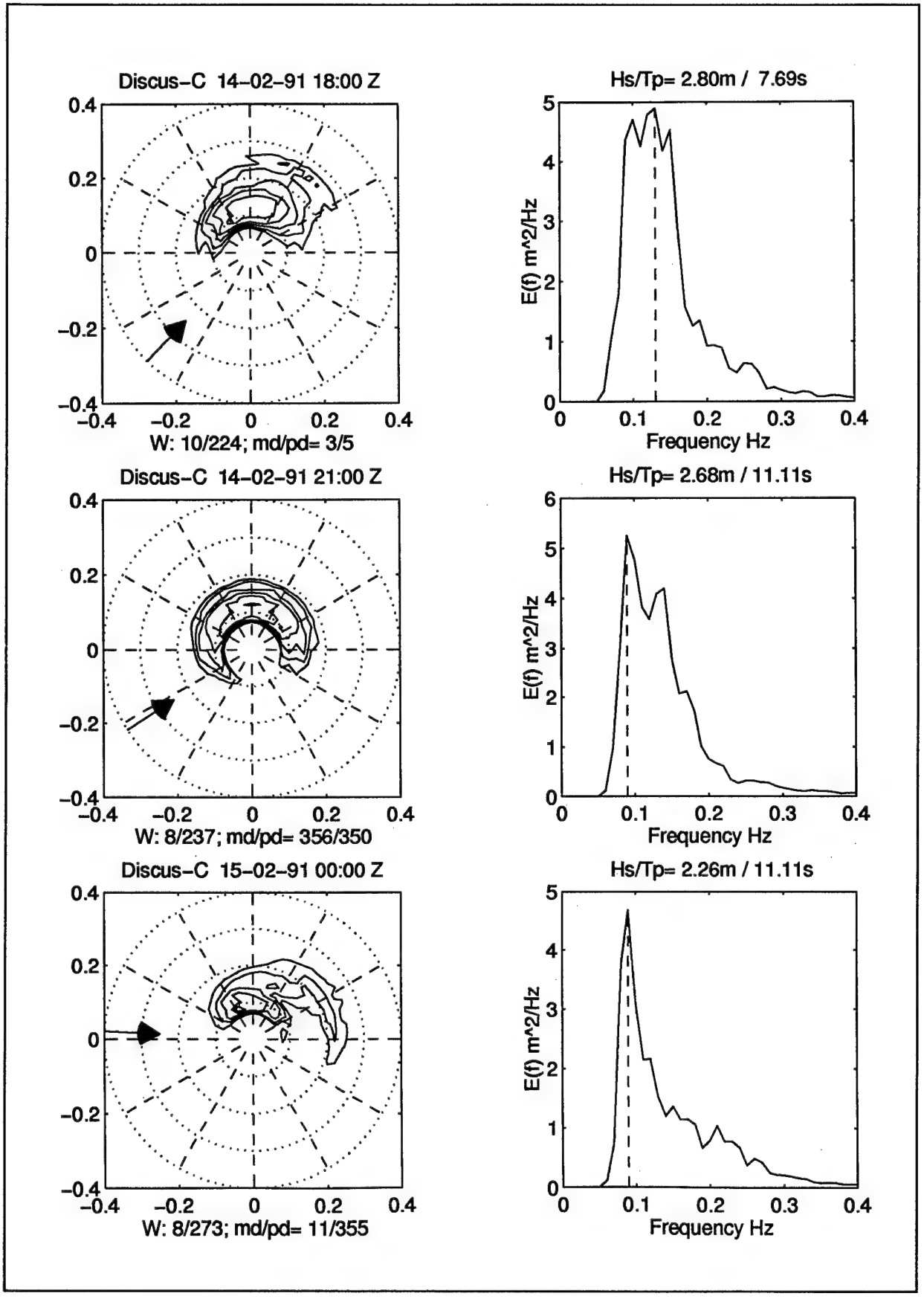

Discus-N 16-02-91 00:00 Z
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
W: 11/288; md/pd= 76/110

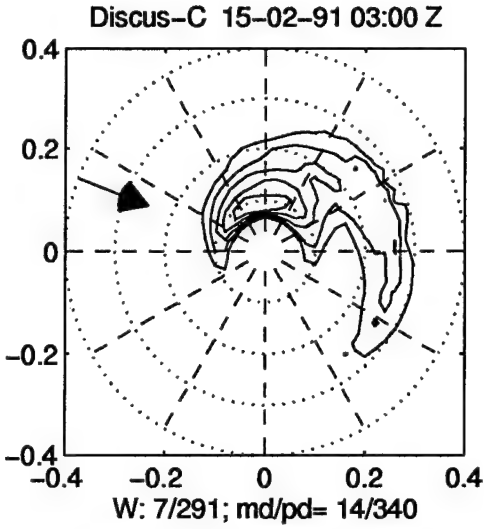

Hs/Tp= 2.58m / 5.88s
E(f) m^2/Hz
5
4
3
2
1
0
0 0.1 0.2 0.3 0.4
Frequency Hz

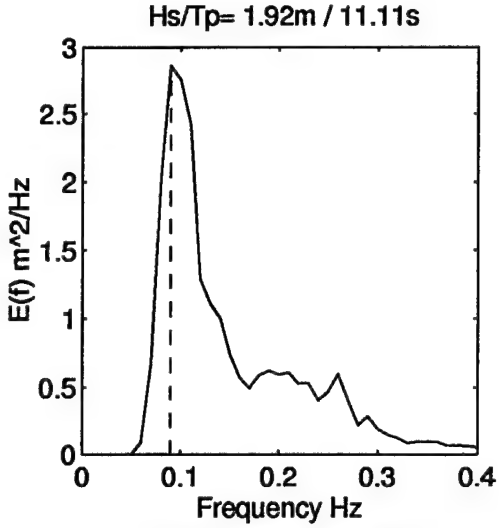
Appendix D3: Discus-East
14-16 February 1991

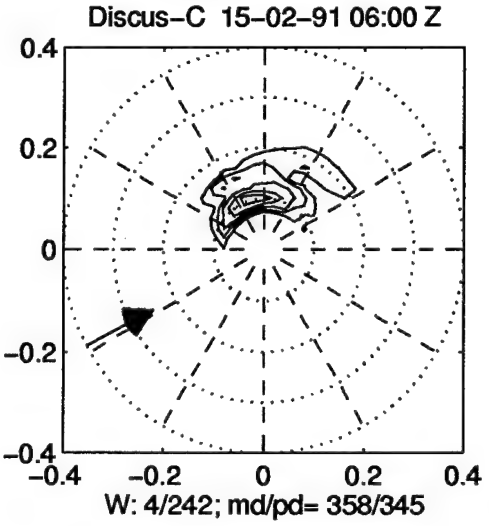

Discus-C 14-02-91 00:00 Z
W: 8/219; md/pd= 11/25
Hs/Tp= 2.15m / 7.69s
E(f) m^2/Hz
Frequency Hz
Discus-C 14-02-91 03:00 Z
W: 1/213; md/pd= 359/345
Hs/Tp= 2.27m / 7.69s
E(f) m^2/Hz
Frequency Hz
Discus-C 14-02-91 06:00 Z
W: 6/204; md/pd= 7/15
Hs/Tp= 1.41m / 7.14s
E(f) m^2/Hz
Frequency Hz

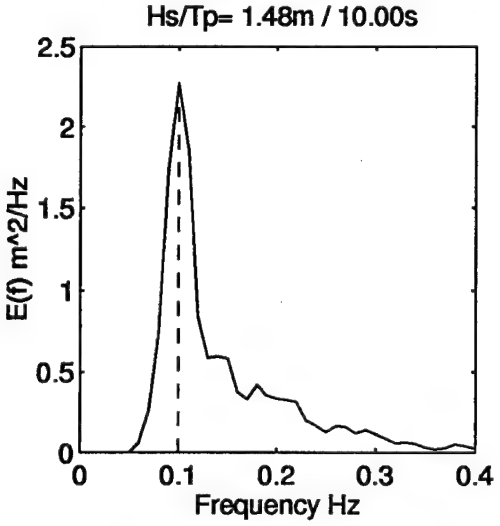

Discus-C 14-02-91 09:00 Z
W: 10/211; md/pd= 9/10
Hs/Tp= 1.56m / 5.88s
E(f) m^2/Hz
Frequency Hz
Discus-C 14-02-91 12:00 Z
W: 8/212; md/pd= 4/355
Hs/Tp= 2.35m / 8.33s
E(f) m^2/Hz
Frequency Hz
Discus-C 14-02-91 15:00 Z
W: 11/199; md/pd= 3/15
Hs/Tp= 2.43m / 8.33s
E(f) m^2/Hz
Frequency Hz

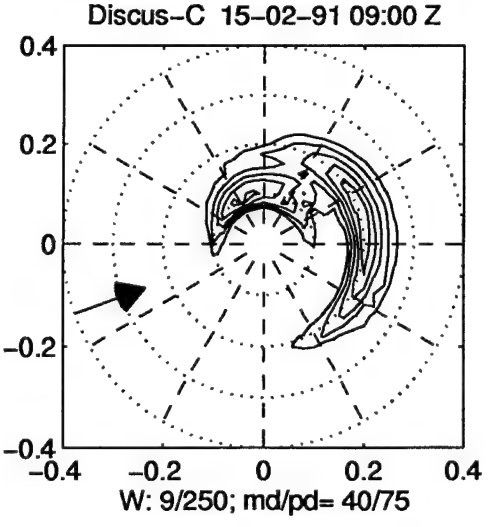

Discus-C 14-02-91 18:00 Z
W: 10/224; md/pd= 3/5
Hs/Tp= 2.80m / 7.69s
E(f) m^2/Hz
Frequency Hz
Discus-C 14-02-91 21:00 Z
W: 8/237; md/pd= 356/350
Hs/Tp= 2.68m / 11.11s
E(f) m^2/Hz
Frequency Hz
Discus-C 15-02-91 00:00 Z
W: 8/273; md/pd= 11/355
Hs/Tp= 2.26m / 11.11s
E(f) m^2/Hz
Frequency Hz

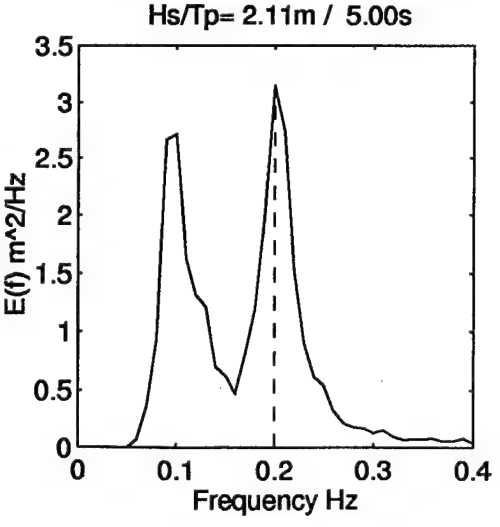

Discus-C 15-02-91 03:00 Z
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
W: 7/291; md/pd= 14/340

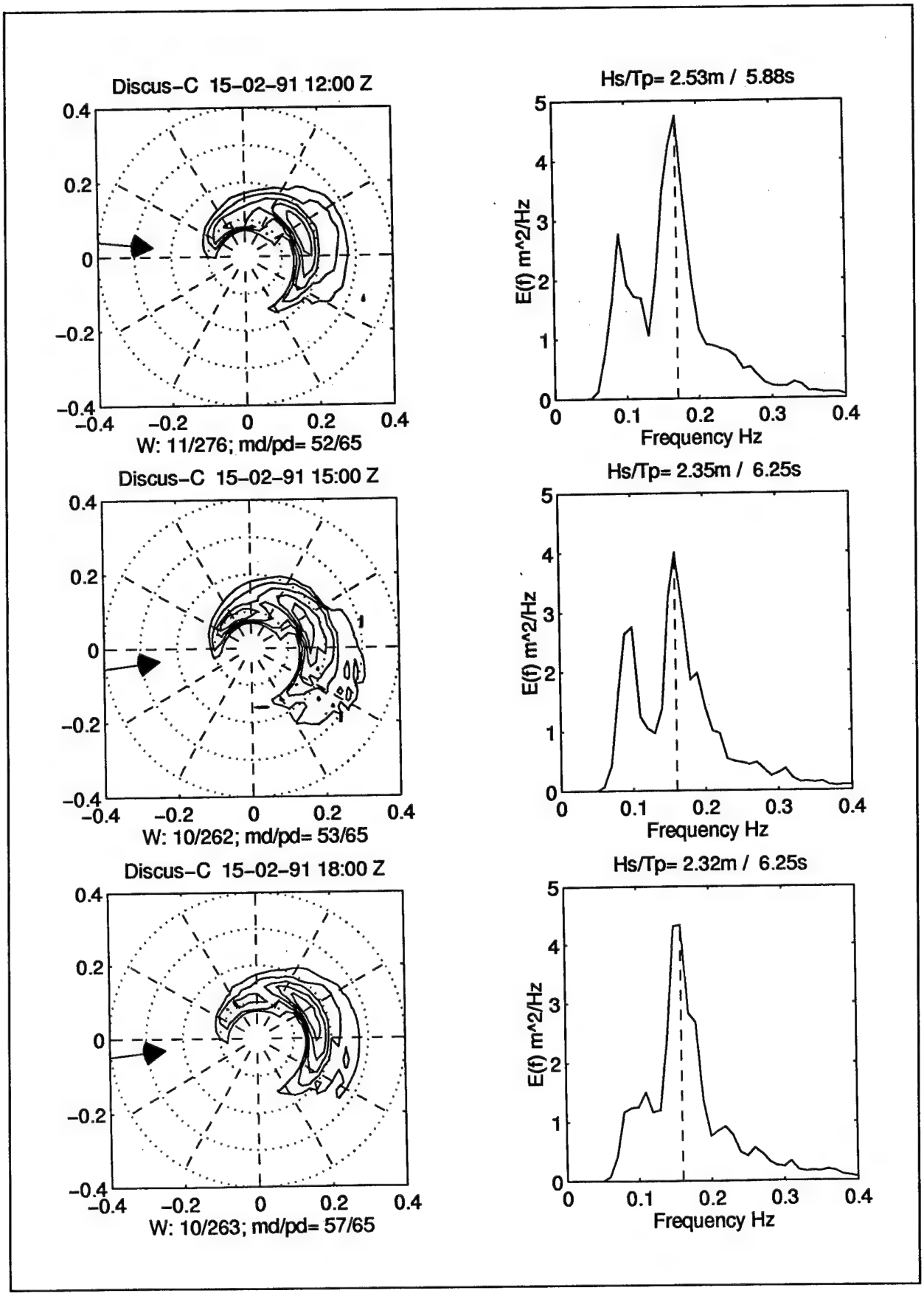

Hs/Tp= 1.92m / 11.11s
E(f) m^2/Hz
3
2.5
2
1.5
1
0.5
0
0 0.1 0.2 0.3 0.4
Frequency Hz

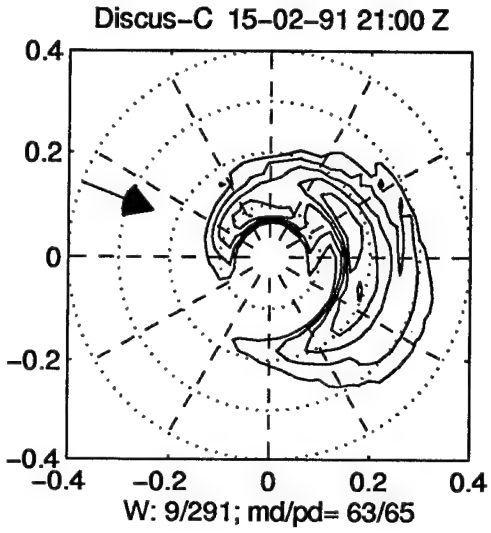

Discus-C 15-02-91 06:00 Z
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
W: 4/242; md/pd= 358/345

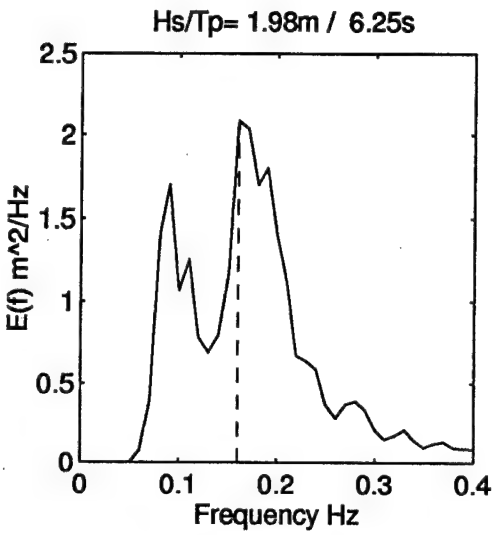

Hs/Tp= 1.48m / 10.00s
E(f) m^2/Hz
2.5
2
1.5
1
0.5
0
0 0.1 0.2 0.3 0.4
Frequency Hz

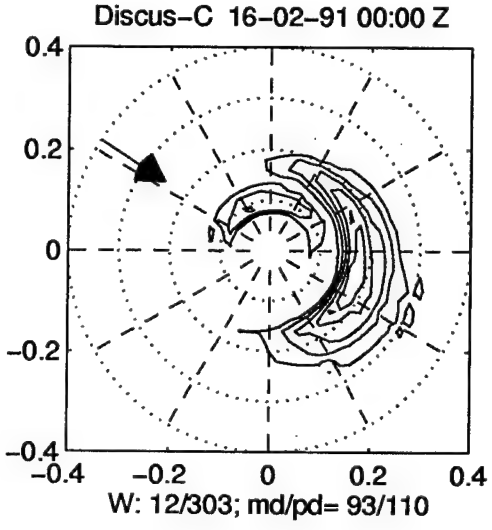

Discus-C 15-02-91 09:00 Z
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
W: 9/250; md/pd= 40/75

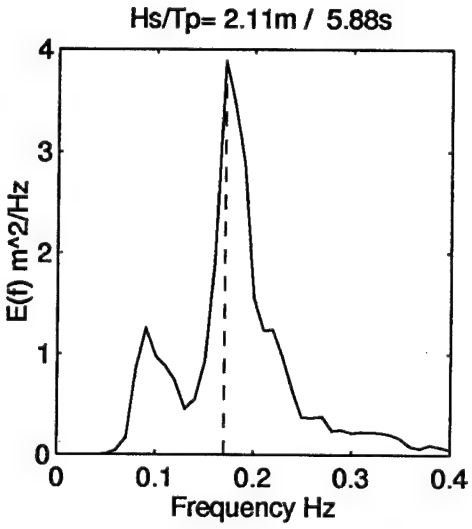

Hs/Tp= 2.11m / 5.00s
E(f) m^2/Hz
3.5
3
2.5
2
1.5
1
0.5
0
0 0.1 0.2 0.3 0.4
Frequency Hz


Discus-C 15-02-91 12:00 Z
W: 11/276; md/pd= 52/65
Hs/Tp= 2.53m / 5.88s
E(f) m^2/Hz
Frequency Hz
Discus-C 15-02-91 15:00 Z
W: 10/262; md/pd= 53/65
Hs/Tp= 2.35m / 6.25s
E(f) m^2/Hz
Frequency Hz
Discus-C 15-02-91 18:00 Z
W: 10/263; md/pd= 57/65
Hs/Tp= 2.32m / 6.25s
E(f) m^2/Hz
Frequency Hz

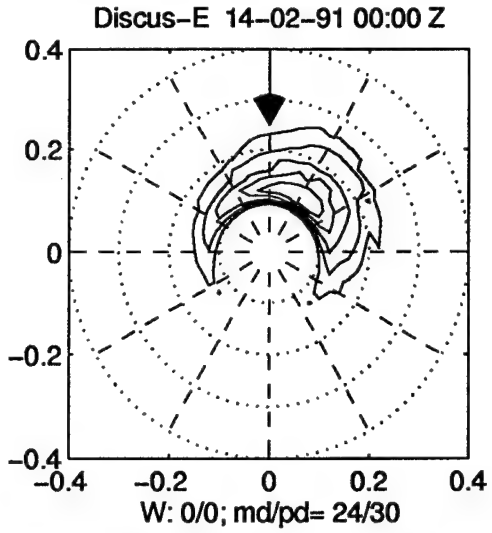

Discus-C 15-02-91 21:00 Z
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
W: 9/291; md/pd= 63/65

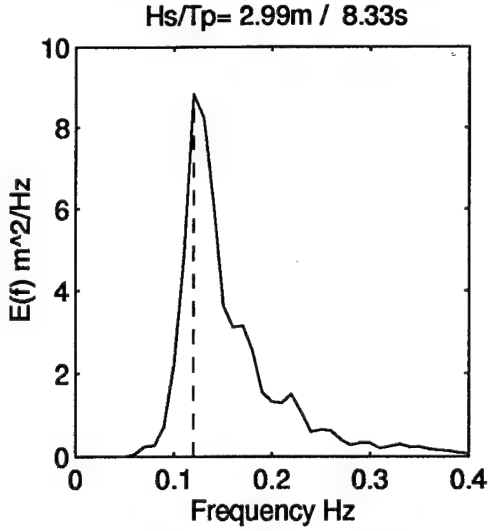

Hs/Tp= 1.98m / 6.25s
2.5
2
1.5
1
0.5
0
E(f) m^2/Hz
0 0.1 0.2 0.3 0.4
Frequency Hz

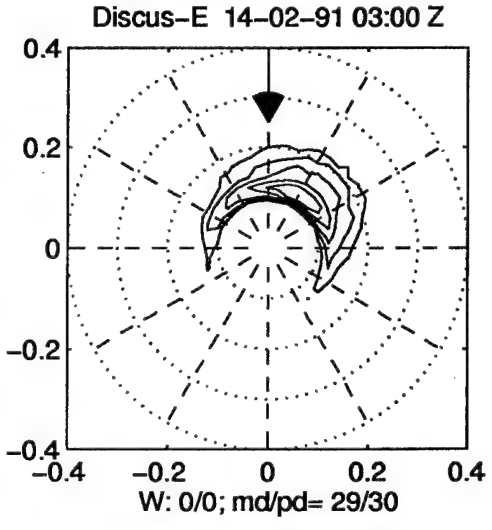

Discus-C 16-02-91 00:00 Z
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
W: 12/303; md/pd= 93/110

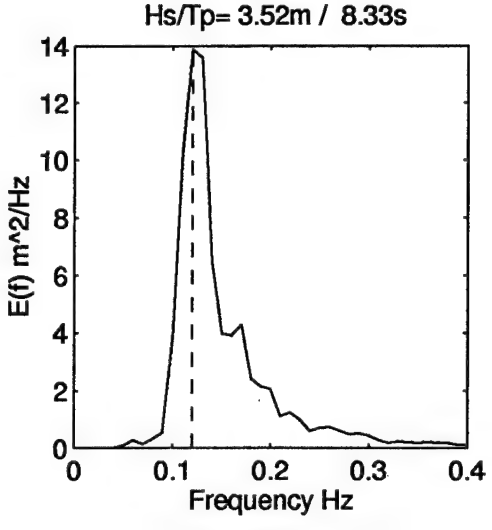

Hs/Tp= 2.11m / 5.88s
4
3
2
1
0
E(f) m^2/Hz
0 0.1 0.2 0.3 0.4
Frequency Hz

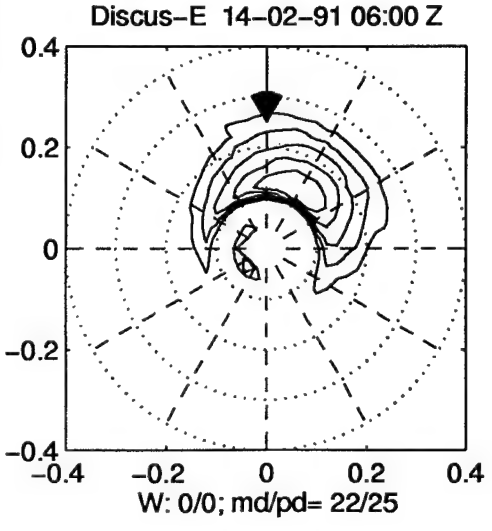
Appendix D4: Discus-Center
14-16 February 1991

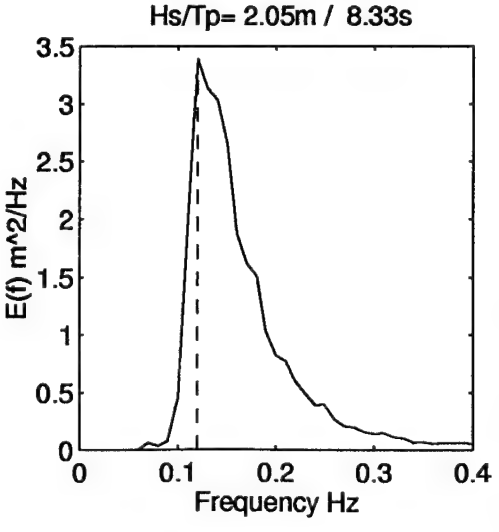

Discus-E 14-02-91 00:00 Z
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
W: 0/0; md/pd= 24/30

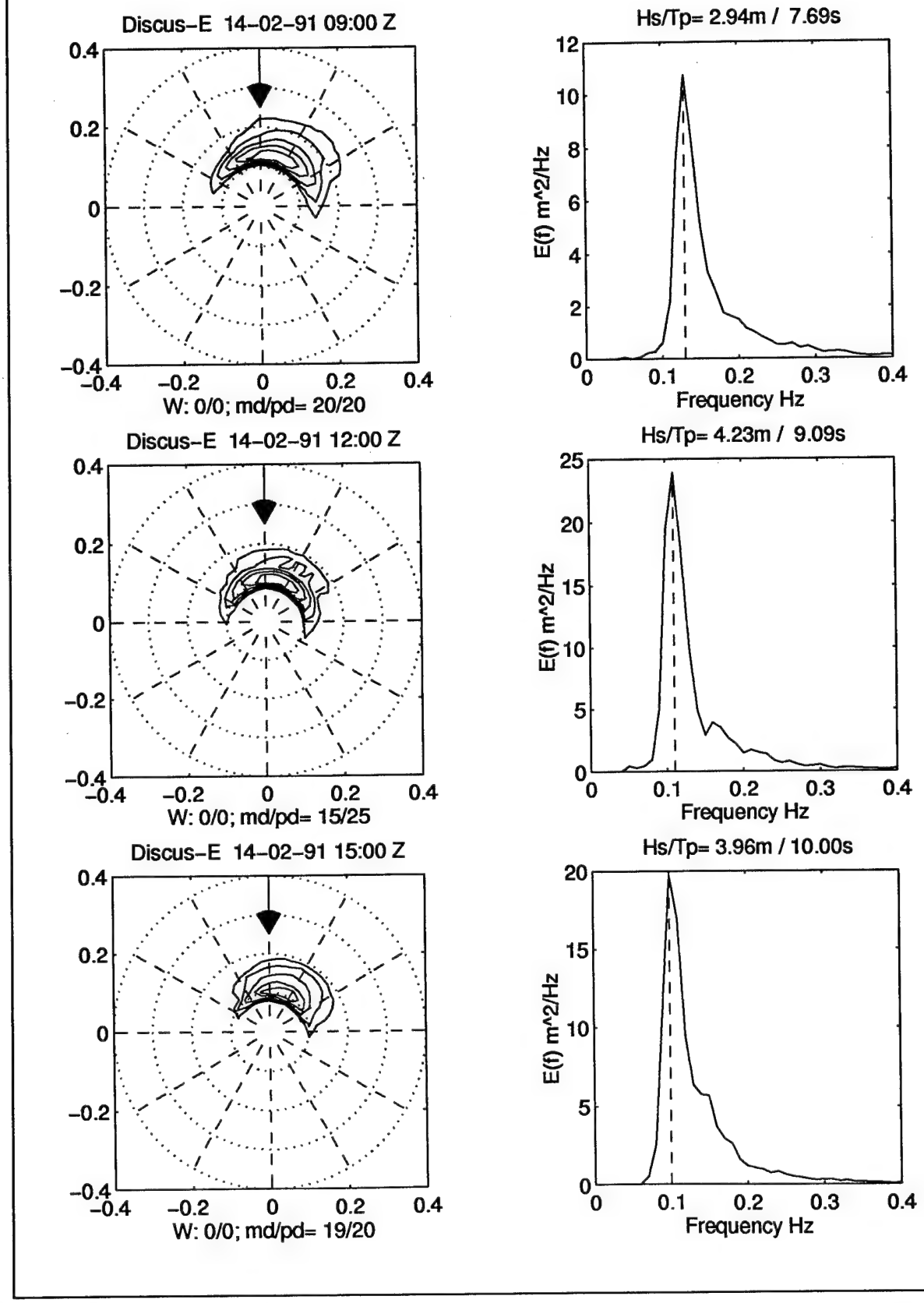

Hs/Tp= 2.99m / 8.33s
E(f) m^2/Hz
10
8
6
4
2
0
0 0.1 0.2 0.3 0.4
Frequency Hz

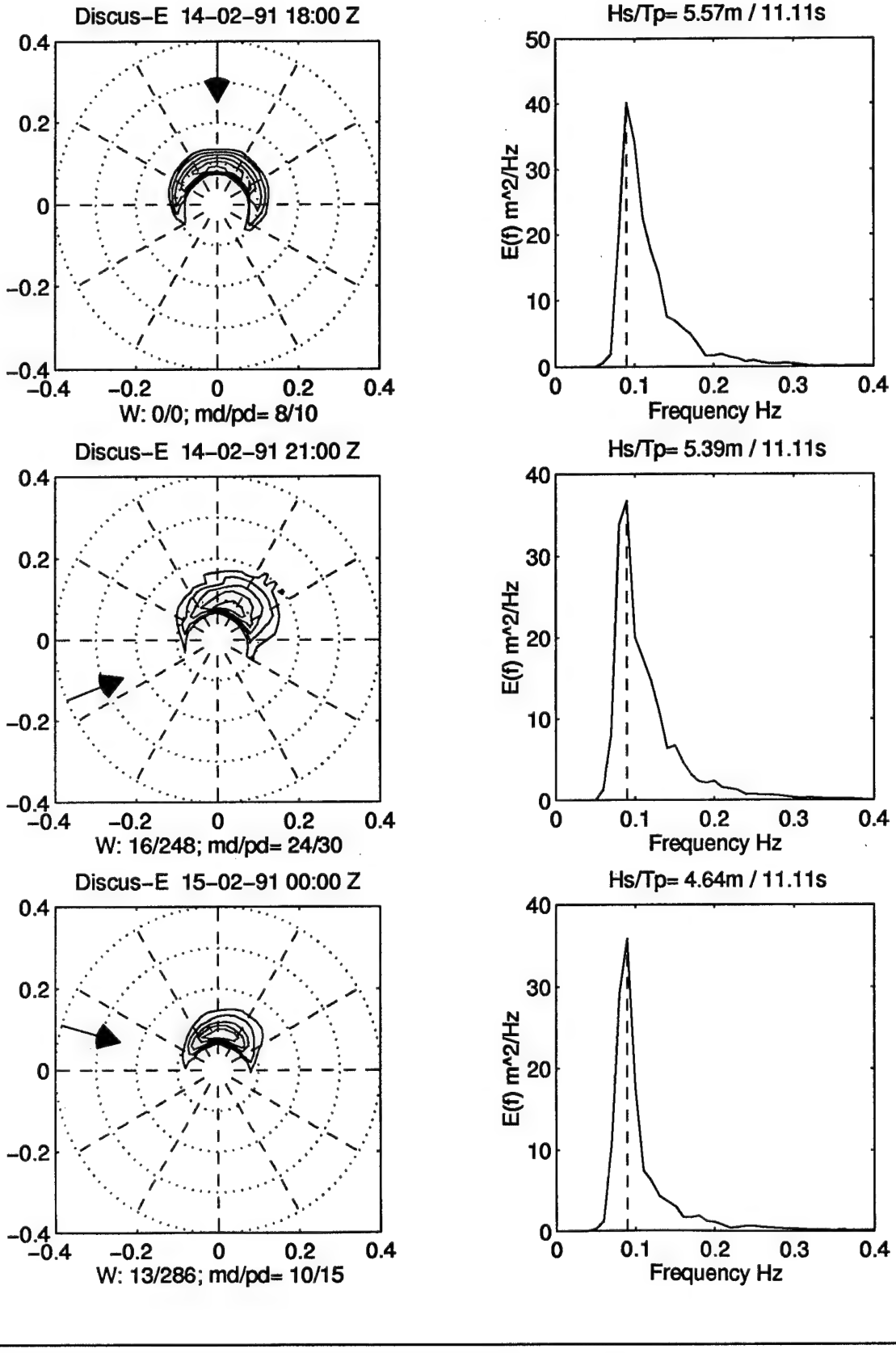

Discus-E 14-02-91 03:00 Z
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
W: 0/0; md/pd= 29/30

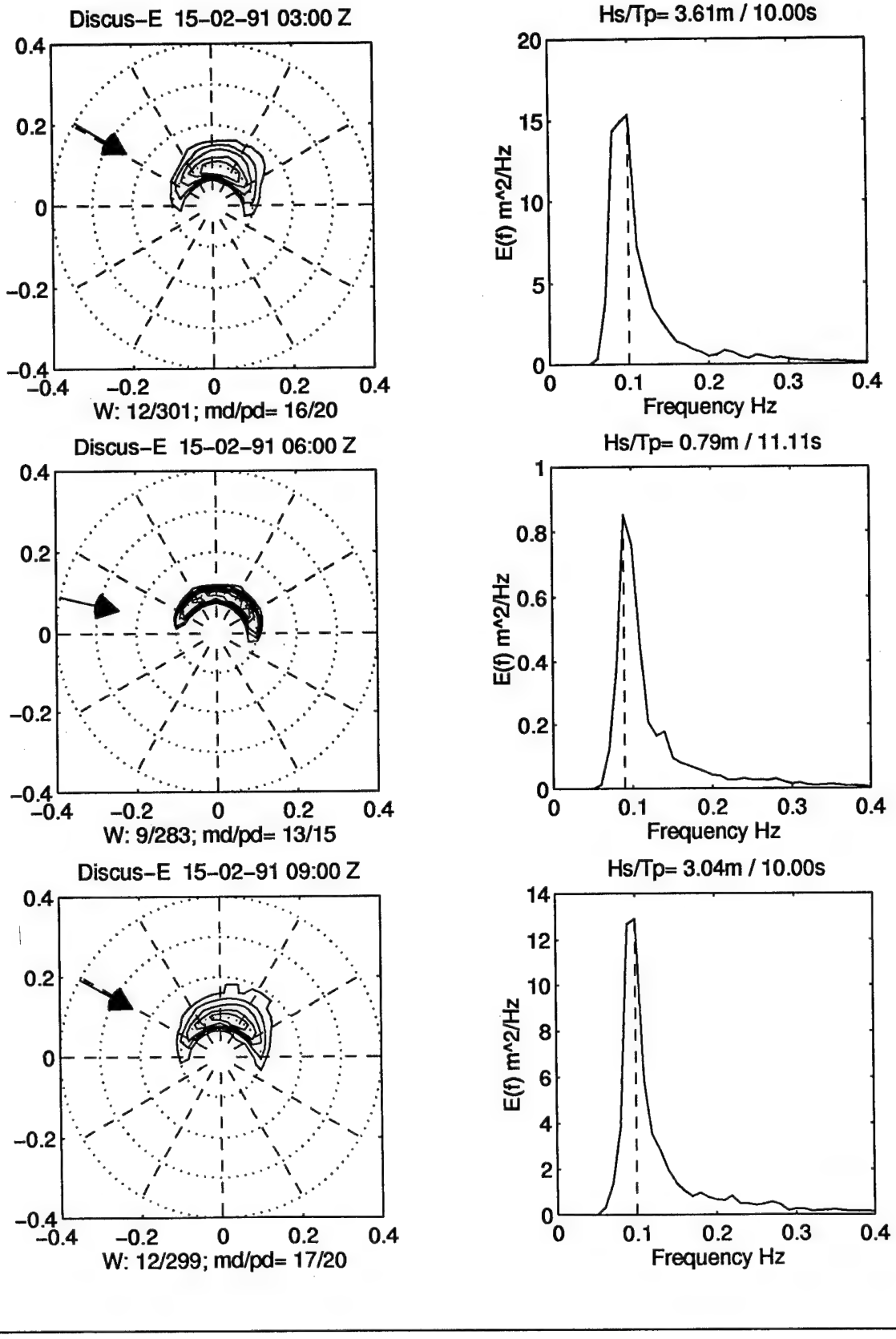

Hs/Tp= 3.52m / 8.33s
E(f) m^2/Hz
14
12
10
8
6
4
2
0
0 0.1 0.2 0.3 0.4
Frequency Hz

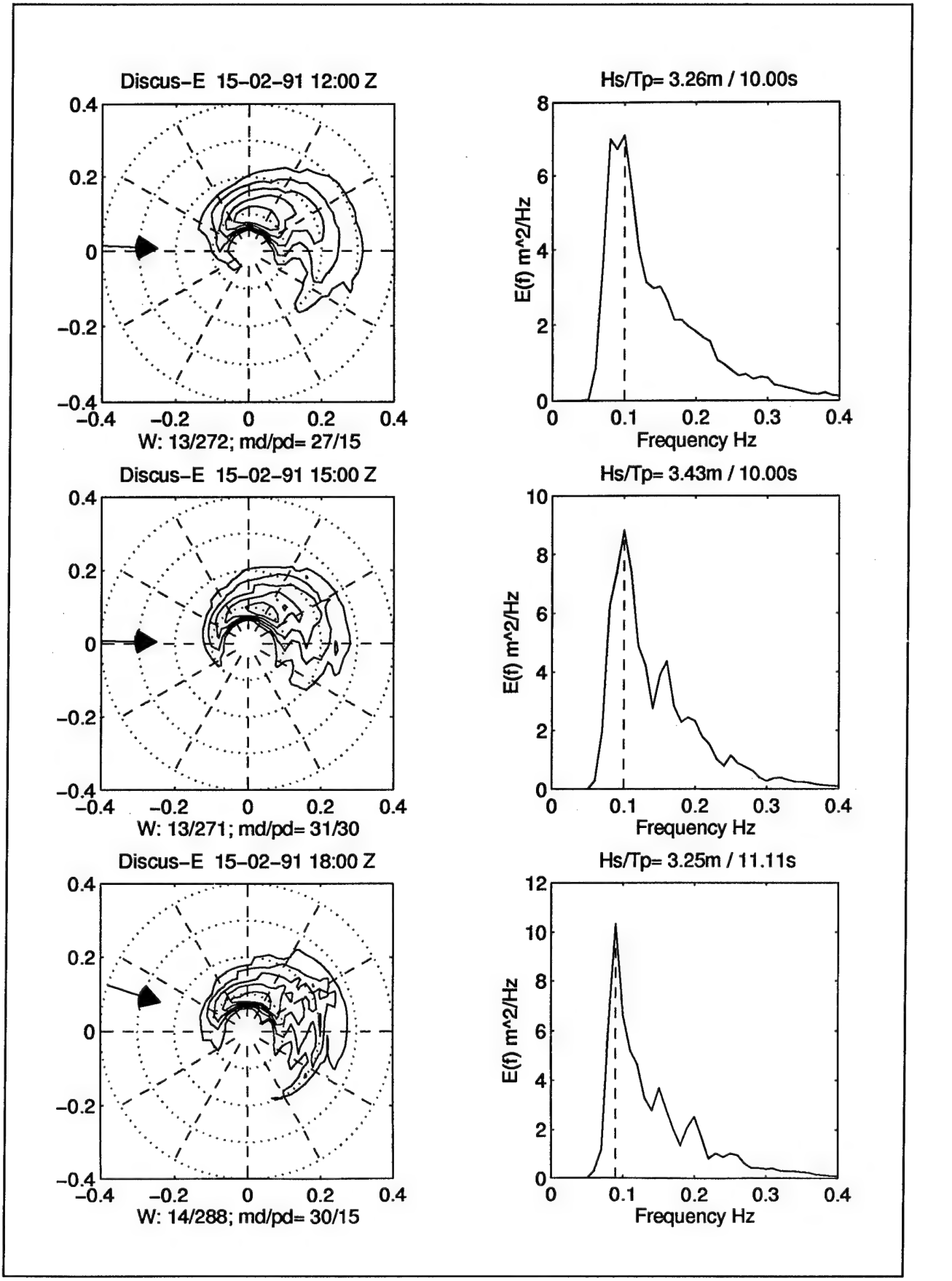

Discus-E 14-02-91 06:00 Z
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
W: 0/0; md/pd= 22/25

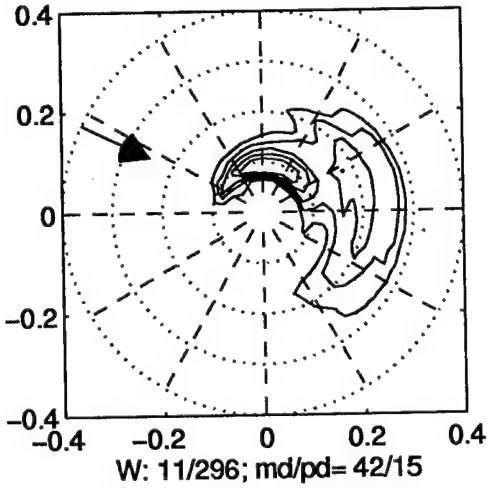

Hs/Tp= 2.05m / 8.33s
E(f) m^2/Hz
3.5
3
2.5
2
1.5
1
0.5
0
0 0.1 0.2 0.3 0.4
Frequency Hz

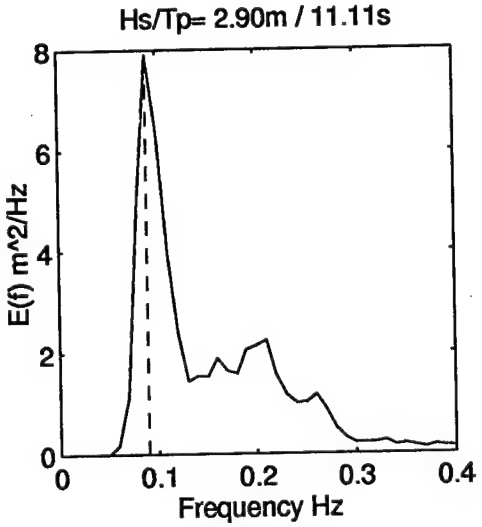

Discus-E 14-02-91 09:00 Z
W: 0/0; md/pd= 20/20
Hs/Tp= 2.94m / 7.69s
E(f) m^2/Hz
Frequency Hz
Discus-E 14-02-91 12:00 Z
W: 0/0; md/pd= 15/25
Hs/Tp= 4.23m / 9.09s
E(f) m^2/Hz
Frequency Hz
Discus-E 14-02-91 15:00 Z
W: 0/0; md/pd= 19/20
Hs/Tp= 3.96m / 10.00s
E(f) m^2/Hz
Frequency Hz

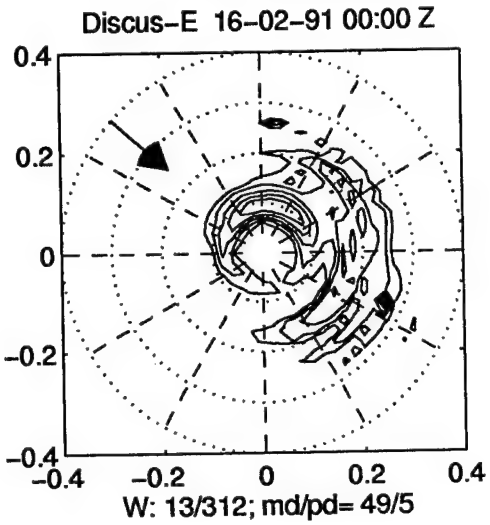

Discus-E 14-02-91 18:00 Z
W: 0/0; md/pd= 8/10
Hs/Tp= 5.57m / 11.11s
E(f) m^2/Hz
Frequency Hz
Discus-E 14-02-91 21:00 Z
W: 16/248; md/pd= 24/30
Hs/Tp= 5.39m / 11.11s
E(f) m^2/Hz
Frequency Hz
Discus-E 15-02-91 00:00 Z
W: 13/286; md/pd= 10/15
Hs/Tp= 4.64m / 11.11s
E(f) m^2/Hz
Frequency Hz

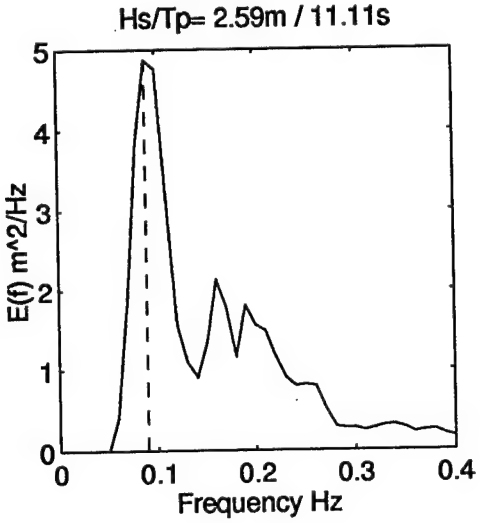

Discus-E 15-02-91 03:00 Z
W: 12/301; md/pd= 16/20
Hs/Tp= 3.61m / 10.00s
E(f) m^2/Hz
Frequency Hz
Discus-E 15-02-91 06:00 Z
W: 9/283; md/pd= 13/15
Hs/Tp= 0.79m / 11.11s
E(f) m^2/Hz
Frequency Hz
Discus-E 15-02-91 09:00 Z
W: 12/299; md/pd= 17/20
Hs/Tp= 3.04m / 10.00s
E(f) m^2/Hz
Frequency Hz


Discus-E 15-02-91 12:00 Z
W: 13/272; md/pd= 27/15
Hs/Tp= 3.26m / 10.00s
E(f) m^2/Hz
Frequency Hz
Discus-E 15-02-91 15:00 Z
W: 13/271; md/pd= 31/30
Hs/Tp= 3.43m / 10.00s
E(f) m^2/Hz
Frequency Hz
Discus-E 15-02-91 18:00 Z
W: 14/288; md/pd= 30/15
Hs/Tp= 3.25m / 11.11s
E(f) m^2/Hz
Frequency Hz

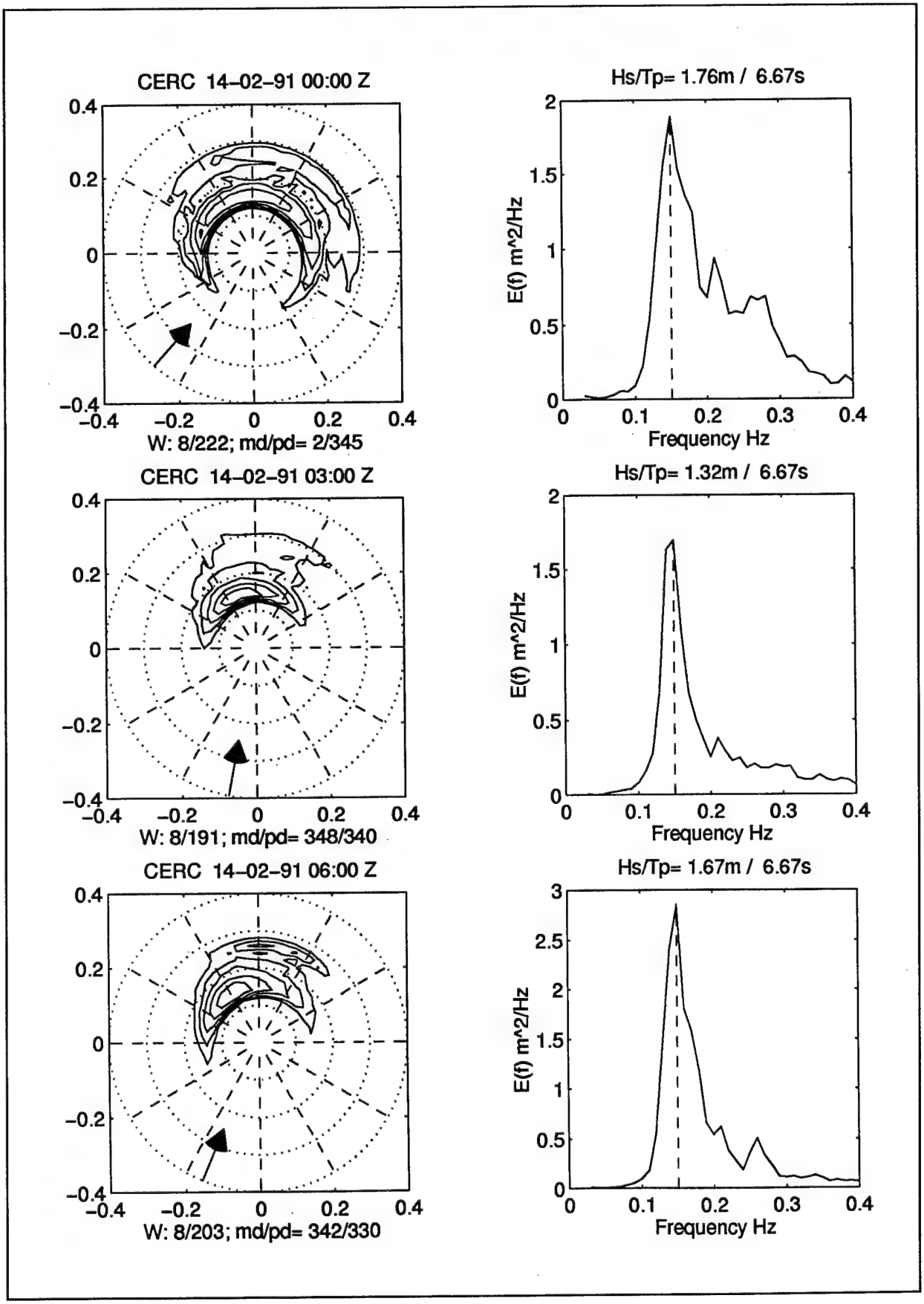

Discus-E 15-02-91 21:00 Z
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
W: 11/296; md/pd= 42/15

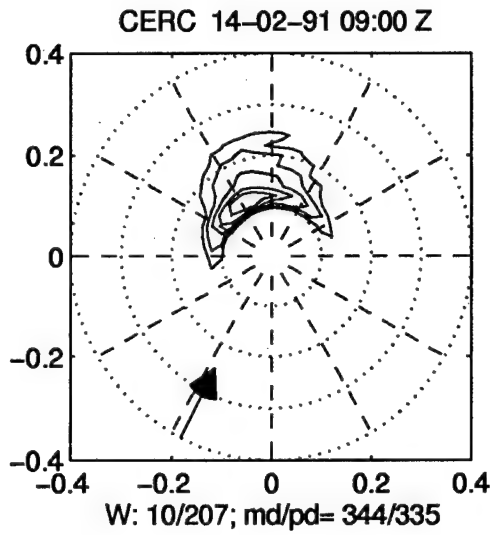

Hs/Tp= 2.90m / 11.11s
E(f) m^2/Hz
0 2 4 6 8
0 0.1 0.2 0.3 0.4
Frequency Hz

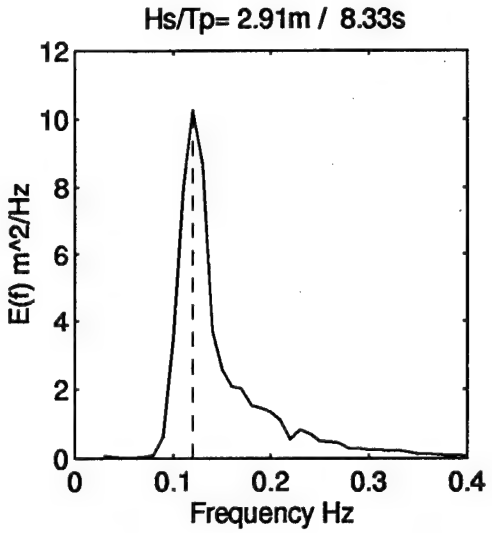

Discus-E 16-02-91 00:00 Z
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
W: 13/312; md/pd= 49/5

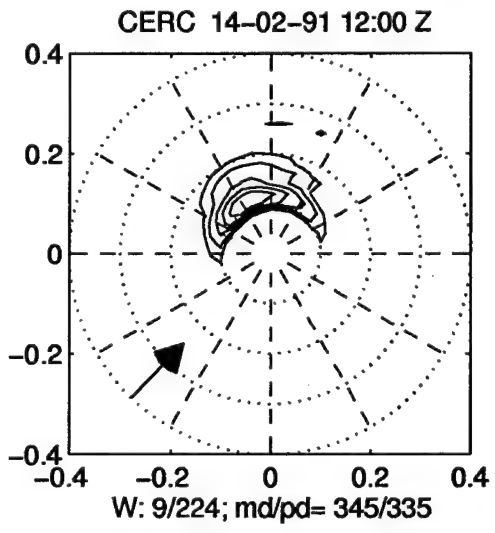

Hs/Tp= 2.59m / 11.11s
E(f) m^2/Hz
0 1 2 3 4 5
0 0.1 0.2 0.3 0.4
Frequency Hz

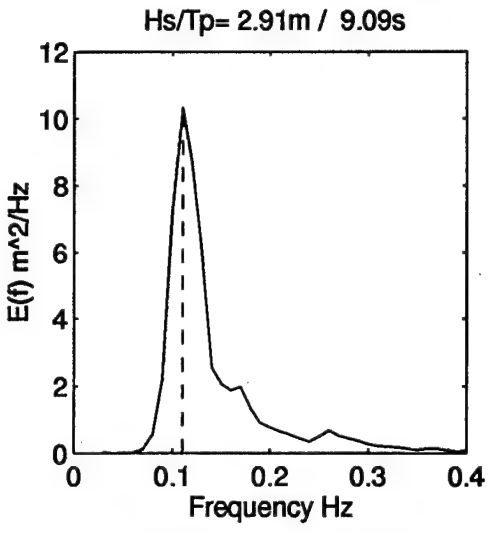
Appendix D5: Buoy CERC
14-16 February 1991

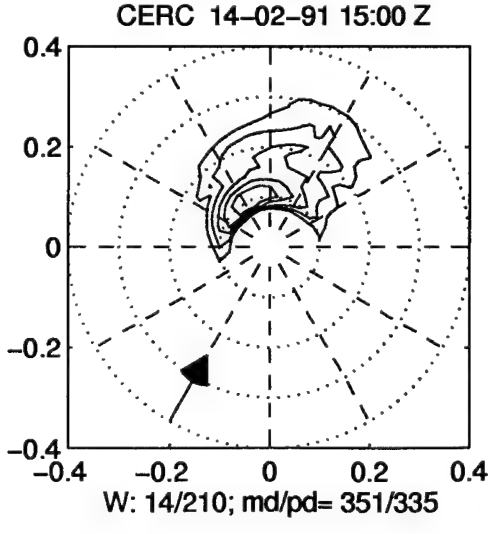

CERC 14-02-91 00:00 Z
W: 8/222; md/pd= 2/345
Hs/Tp= 1.76m / 6.67s
E(f) m^2/Hz
Frequency Hz
CERC 14-02-91 03:00 Z
W: 8/191; md/pd= 348/340
Hs/Tp= 1.32m / 6.67s
E(f) m^2/Hz
Frequency Hz
CERC 14-02-91 06:00 Z
W: 8/203; md/pd= 342/330
Hs/Tp= 1.67m / 6.67s
E(f) m^2/Hz
Frequency Hz

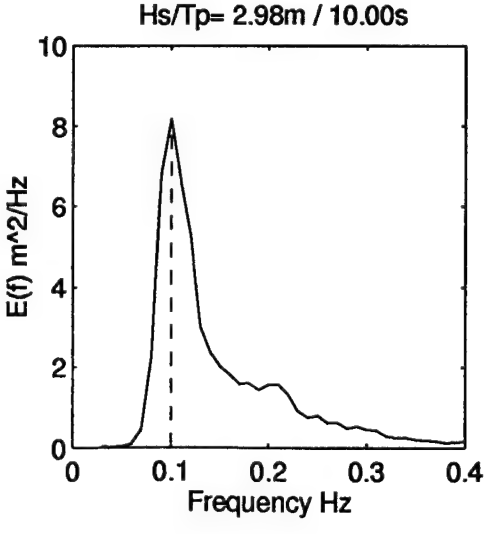

CERC 14-02-91 09:00 Z
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
W: 10/207; md/pd= 344/335

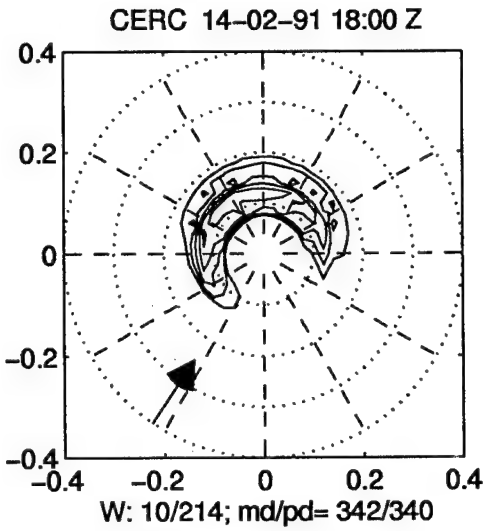

Hs/Tp= 2.91m / 8.33s
E(f) m^2/Hz
12
10
8
6
4
2
0
0 0.1 0.2 0.3 0.4
Frequency Hz

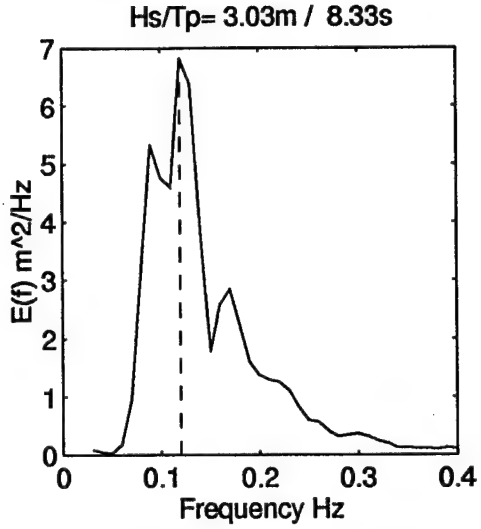

CERC 14-02-91 12:00 Z
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
W: 9/224; md/pd= 345/335

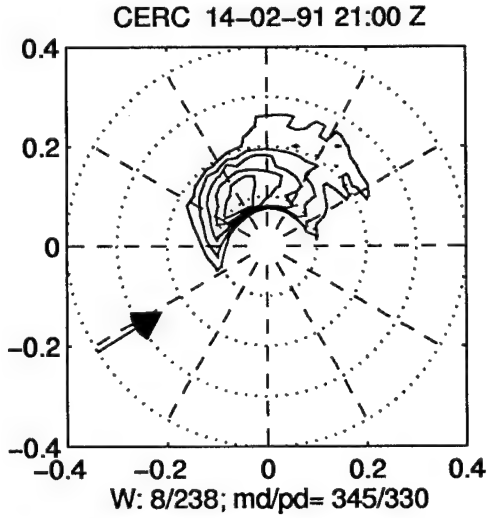

Hs/Tp= 2.91m / 9.09s
E(f) m^2/Hz
12
10
8
6
4
2
0
0 0.1 0.2 0.3 0.4
Frequency Hz

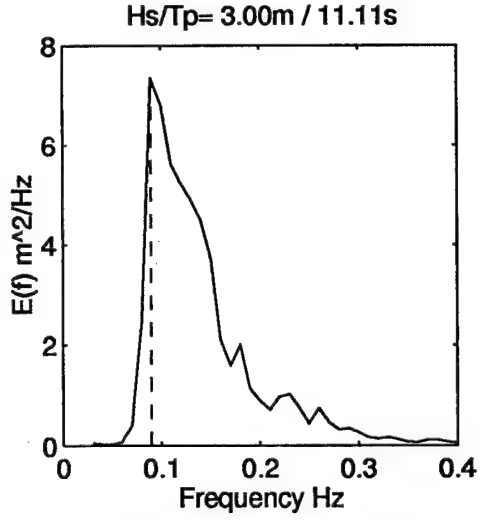

CERC 14-02-91 15:00 Z
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
W: 14/210; md/pd= 351/335

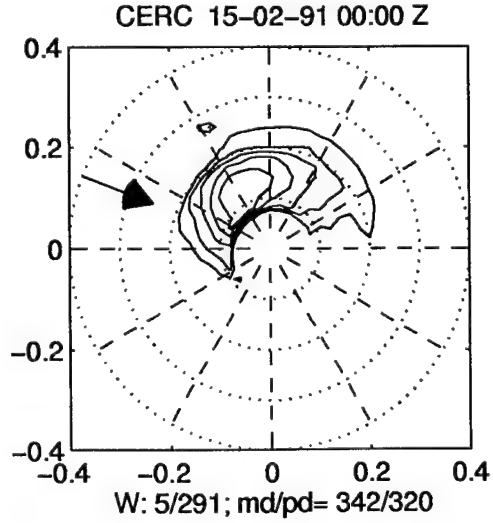

Hs/Tp= 2.98m / 10.00s
E(f) m^2/Hz
10
8
6
4
2
0
0 0.1 0.2 0.3 0.4
Frequency Hz

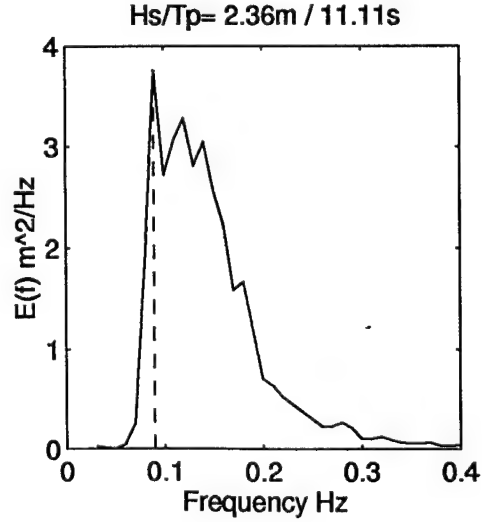

CERC 14-02-91 18:00 Z
W: 10/214; md/pd= 342/340

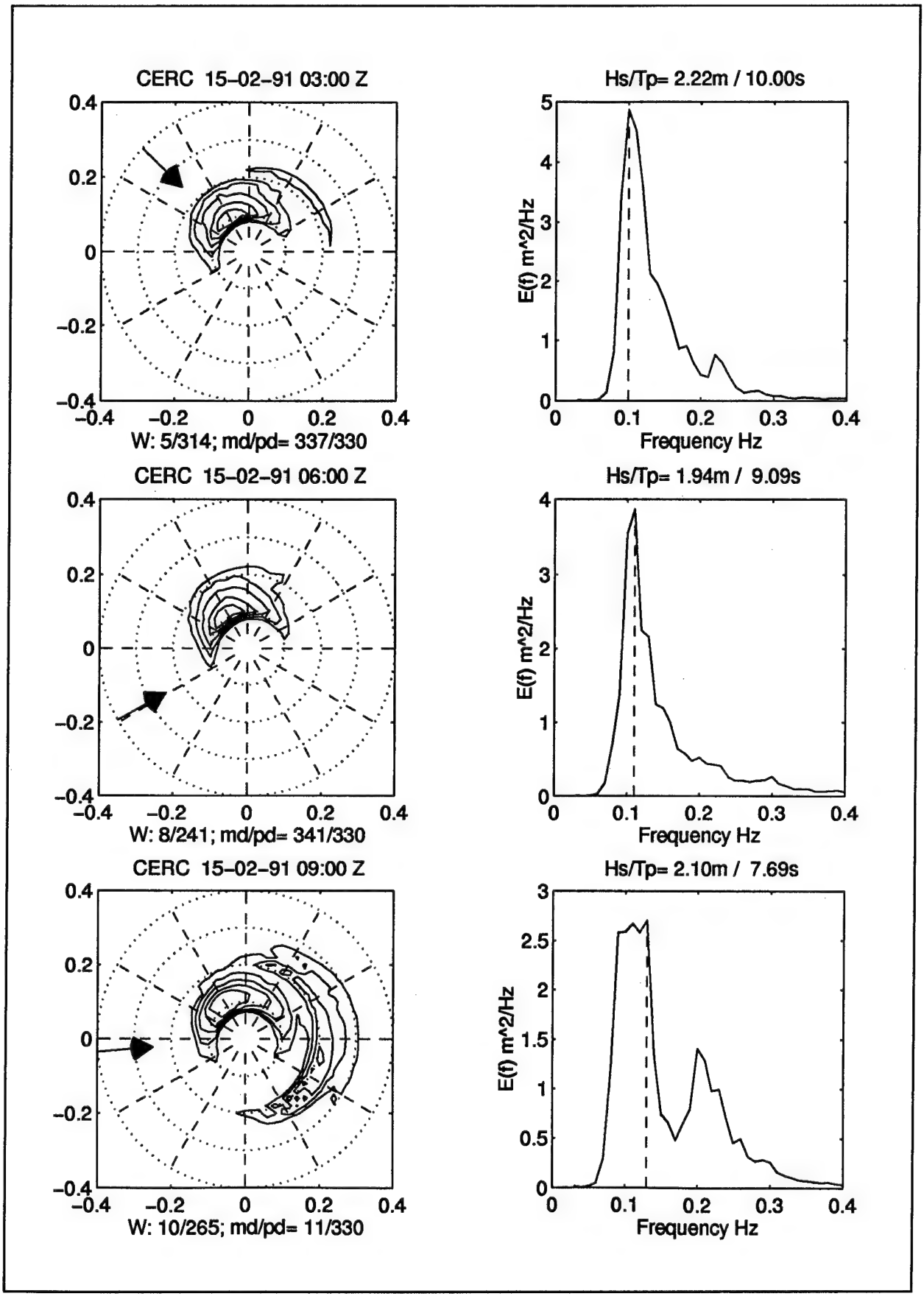

Hs/Tp= 3.03m / 8.33s
E(f) m^2/Hz
Frequency Hz

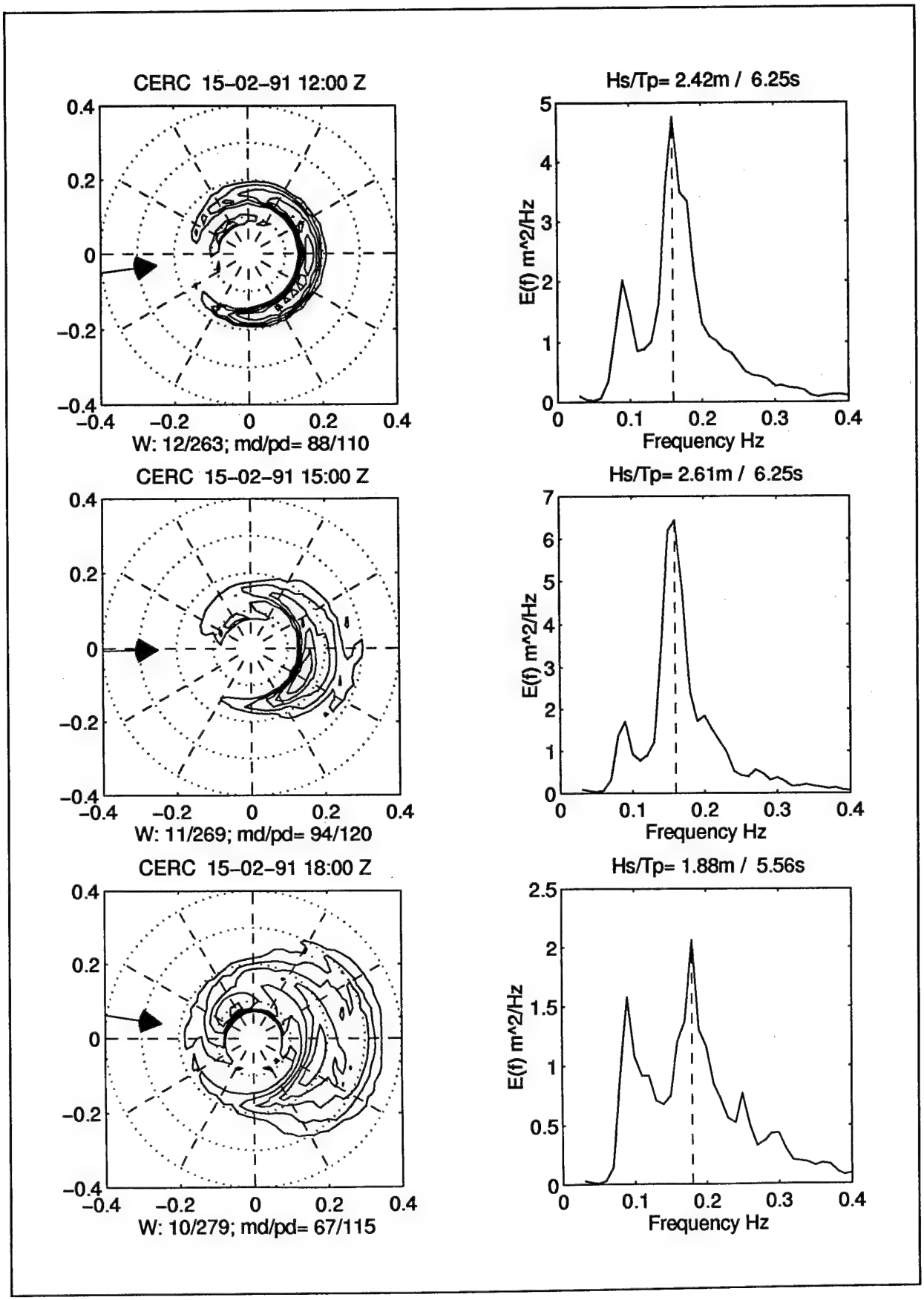

CERC 14-02-91 21:00 Z
W: 8/238; md/pd= 345/330

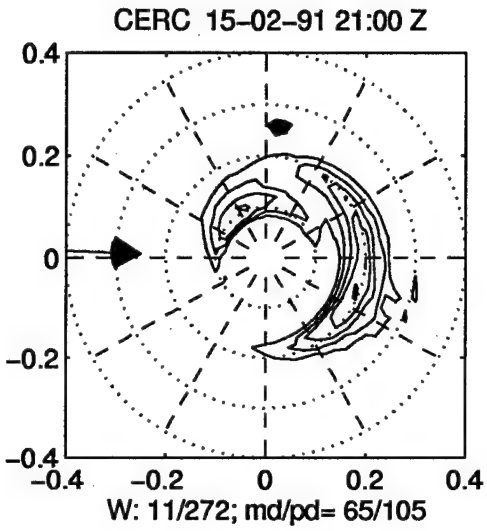

Hs/Tp= 3.00m / 11.11s
E(f) m^2/Hz
Frequency Hz

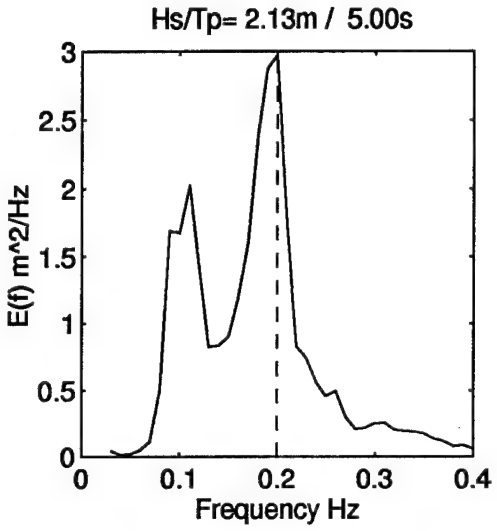

CERC 15-02-91 00:00 Z
W: 5/291; md/pd= 342/320

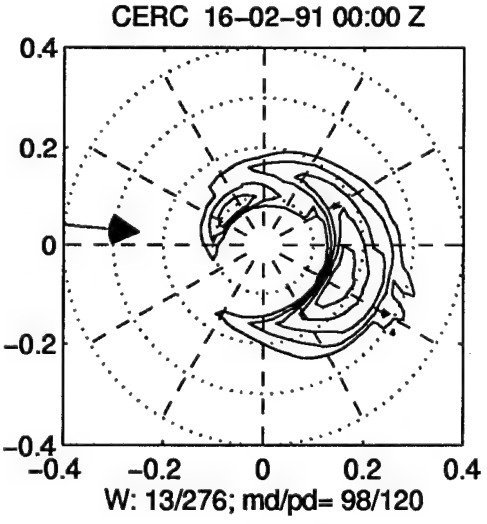

Hs/Tp= 2.36m / 11.11s
E(f) m^2/Hz
Frequency Hz

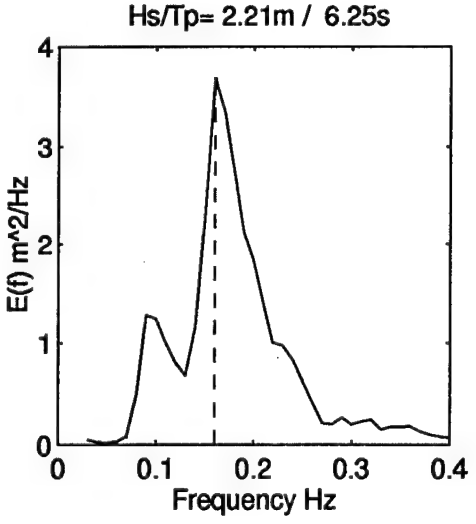

CERC 15-02-91 03:00 Z
W: 5/314; md/pd= 337/330
Hs/Tp= 2.22m / 10.00s
E(f) m^2/Hz
Frequency Hz
CERC 15-02-91 06:00 Z
W: 8/241; md/pd= 341/330
Hs/Tp= 1.94m / 9.09s
E(f) m^2/Hz
Frequency Hz
CERC 15-02-91 09:00 Z
W: 10/265; md/pd= 11/330
Hs/Tp= 2.10m / 7.69s
E(f) m^2/Hz
Frequency Hz


CERC 15-02-91 12:00 Z
W: 12/263; md/pd= 88/110
Hs/Tp= 2.42m / 6.25s
E(f) m^2/Hz
Frequency Hz
CERC 15-02-91 15:00 Z
W: 11/269; md/pd= 94/120
Hs/Tp= 2.61m / 6.25s
E(f) m^2/Hz
Frequency Hz
CERC 15-02-91 18:00 Z
W: 10/279; md/pd= 67/115
Hs/Tp= 1.88m / 5.56s
E(f) m^2/Hz
Frequency Hz


CERC 15-02-91 21:00 Z
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
W: 11/272; md/pd= 65/105


Hs/Tp= 2.13m / 5.00s
E(f) m^2/Hz
3
2.5
2
1.5
1
0.5
0
0 0.1 0.2 0.3 0.4
Frequency Hz


CERC 16-02-91 00:00 Z
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
W: 13/276; md/pd= 98/120


Hs/Tp= 2.21m / 6.25s
E(f) m^2/Hz
4
3
2
1
0
0 0.1 0.2 0.3 0.4
Frequency Hz

Appendix E
ROWS Spectra,
12 February - 7 March 1991

ROWS directional and nondirectional spectra are presented in this appendix in a format identical to that used for the buoy spectra in Appendix D. Note, however, that in the case of these spectra the peak period and direction data are precise, each having been obtained by parabolic fit to the binned spectrum data.

In low sea state cases (SWH _ 2 m), the ROWS spectra may be subject to a fair amount of 'dc' contamination. The nondirectional spectrum and inferred SWH will then depend critically on the imposed low-frequency cutoff. In some cases the choice of cutoff frequency is obvious from the directional spectrum. In others, the choice of cutoff frequency is rather arbitrary. Often the nondirectional spectrum will have no clearly defined peak. The apparent peak in the nondirectional spectrum plot will then simply reflect the choice of cutoff frequency.

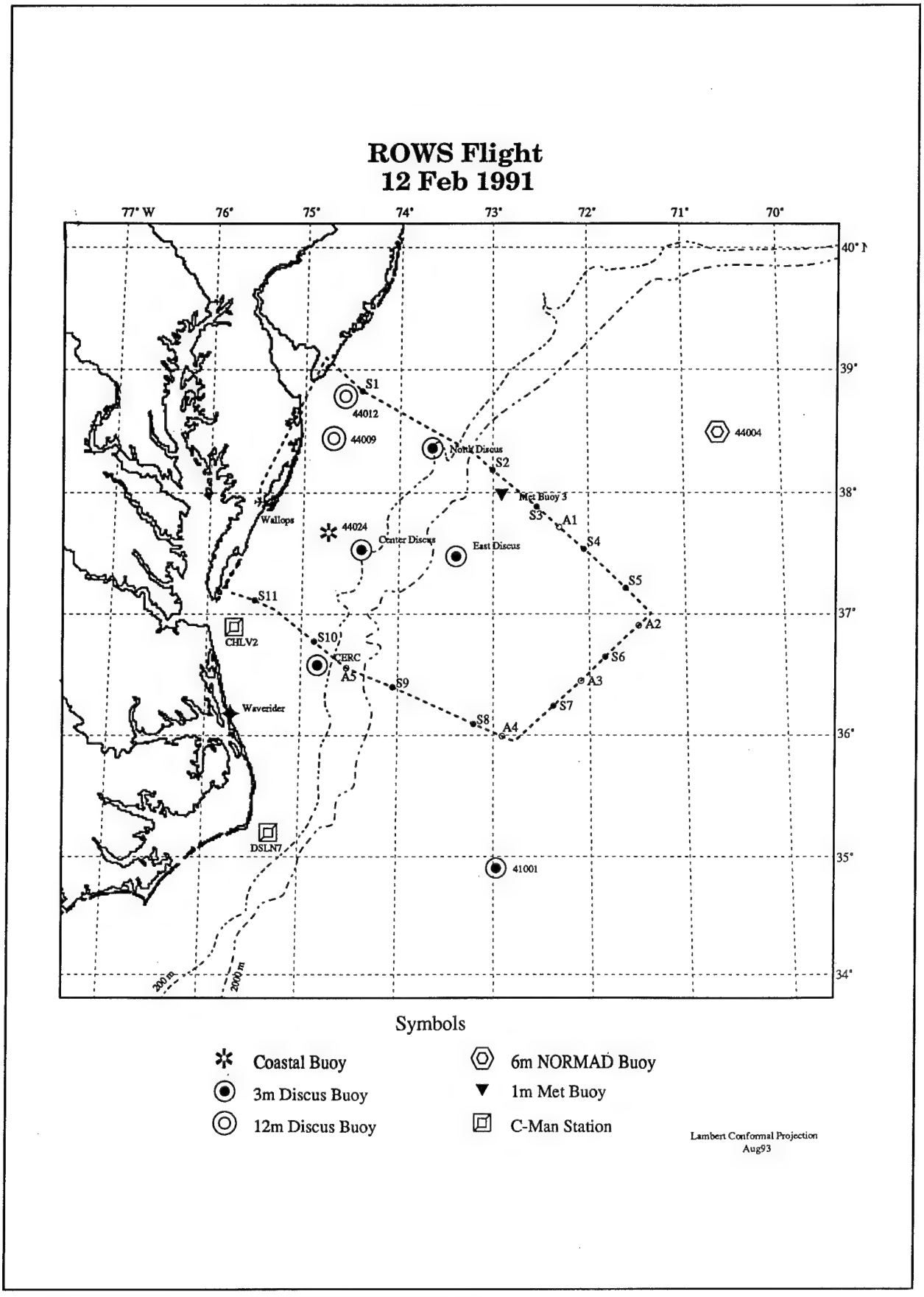
Note that the ROWS wind speeds are from the interpolation fields based on uncorrected full waveform fit altimeter data; thus they are biased low by about 1 ms^{-1} on average.

The spectra plots for each flight are preceded by a flight map and navigation and file data table. On the flight maps the spectra files are denoted by 'S1.' 'S2,' *etc.* and the altimeter mode files are denoted by 'A1,' 'A2,' etc. The flight data table column entries are:

TAPE/FILE	Original tape number for flight and processed file number
POS FIX	Position fix (used to construct flight maps)
ROWS MODE	1 = Spectrometer mode; 2 = Altimeter mode
BUOY/WP	Identifies buoy overflown or way point reached
EST	Center time for particular file in Eastern Standard Time

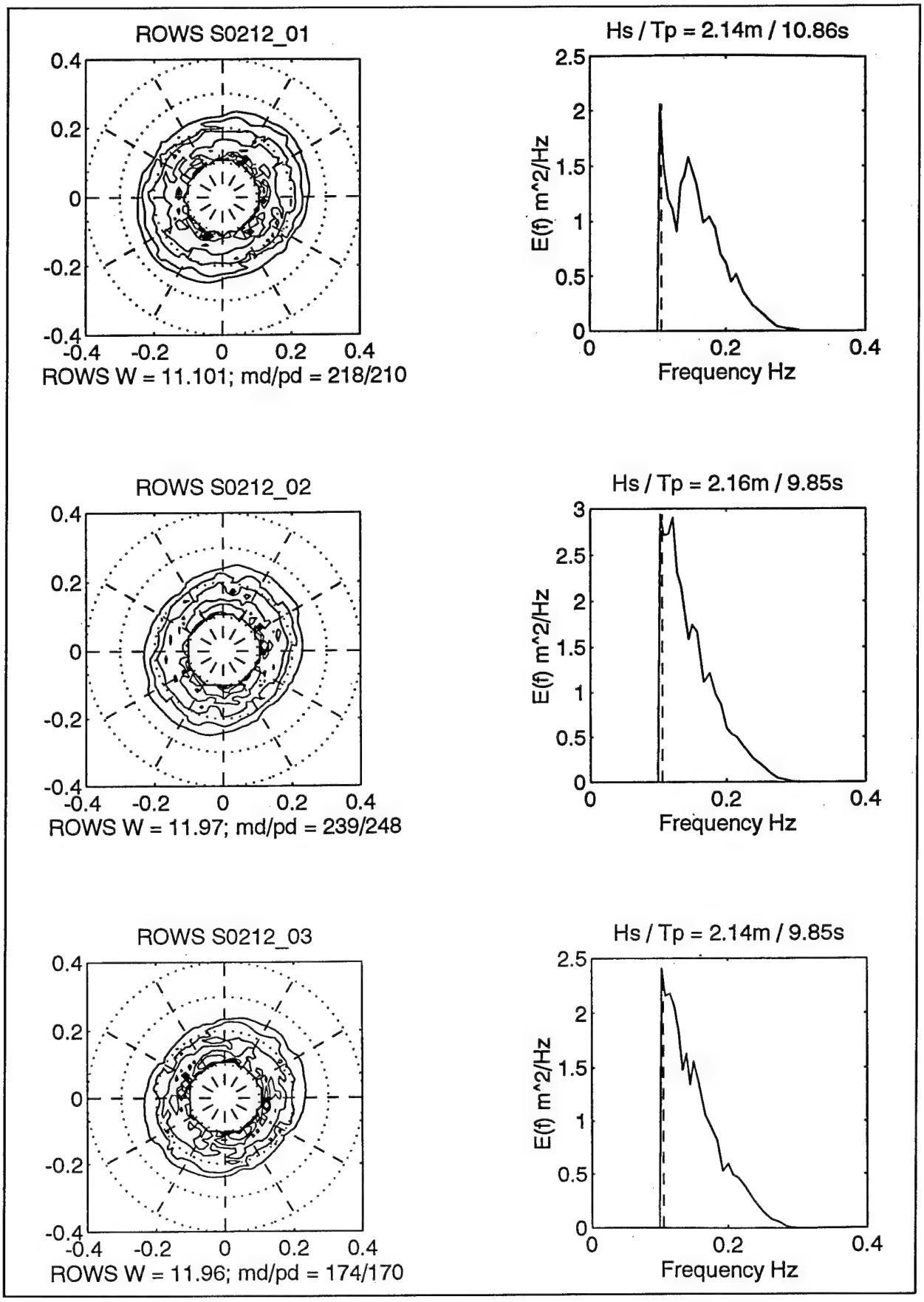
LAT, LON	Latitude (north) and longitude (east) in degrees and decimal
ALT	Aircraft standard pressure altitude in meters
SPD	Aircraft ground speed in m/s
HDG	True heading
PC-TIC	Onboard computer 'tic' time on data tape (hhmmss)
REC #	Start record number on flight data tape
LEN	Length of file to be processed in MB

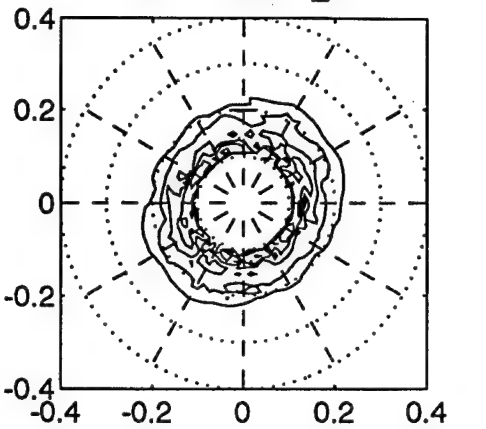
Appendix E1: ROWS Spectra, 12 February 1991


ROWS Flight
12 Feb 1991
77° W
76°
75°
74°
73°
72°
71°
70°
40° N
39°
38°
37°
36°
35°
34°
S1
44012
44009
44004
North Discus
S2
Met Buoy 3
S3
A1
S4
S5
A2
S6
A3
S7
A4
S8
S9
A5
S10
CERC
S11
CHLV2
Wallops
44024
Center Discus
East Discus
Waverider
DSLN7
41001
200 m
2000 m
Symbols
Coastal Buoy
3m Discus Buoy
12m Discus Buoy
6m NORMAD Buoy
1m Met Buoy
C-Man Station
Lambert Conformal Projection
Aug93

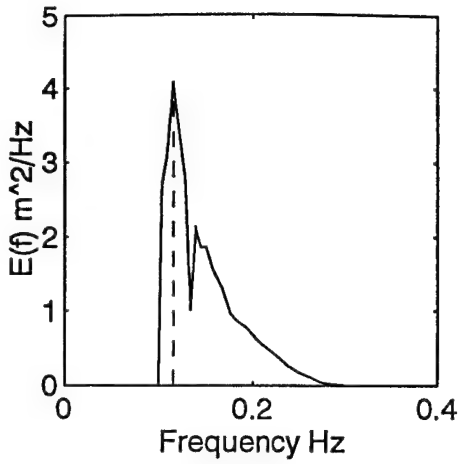
ROWS SWADE FLIGHT NAVIGATION AND FILE DATA
FEB 12, 1991

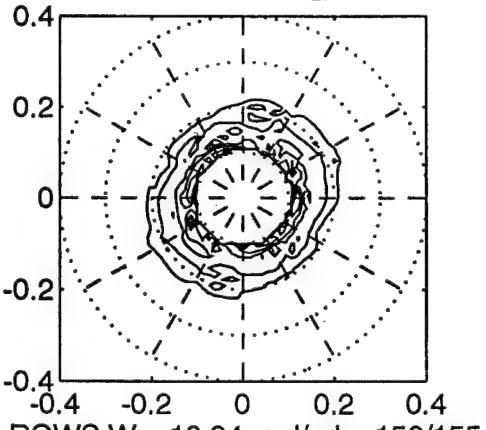
TAPE1/1 FILE	POS FIX	ROWS MODE	BUOY/ WP	EST HH	MM	SS	LAT	LON	ALT	SPD M/S	HDG TRU	PC-TIC START	REC # START	0 DEG DELTA	LEN MB
	1	0	WFF				37.94	-75.47							
	1	0	2	12	23	30	38.06	-75.47							
	1	0	3				39.10	-74.80	7620						
S01	0	1		12	27	04	38.83	-74.40	7620	231	140	122525	5301		12
	1	0	4	12	28	20	38.80	-74.32							
	1	0	5′	12	35	50	38.32	-73.20	7320	238	125				
S02	0	1		12	37	20	38.19	-73.01	7320	235	128	123527	40801		12
	1	0		12	40	00	37.97	-72.67	7320	232	132				
S03	0	1		12	41	00	37.89	-72.55	7320	232	132	123902	62201		12
A01	0	2		12	43	00	37.72	-72.31	7320	232	132	124203	76101		1
S04	0	1		12	45	10	37.54	-72.05	7320	233	135	124315	80201		12
	1	0		12	46	00	37.47	-71.95	7320	233	135				
S05	1	1		12	49	00	37.22	-71.62	7320	234	135	124712	103901		12
	1	0	6	12	50	20	37.01	-71.36	7320						
A02	0	2		12	52	35	36.91	-71.49	7320	165	242	125134	118501		1
	1	0		12	54	15	36.82	-71.62	7320	167	242				
S06	0	1		12	56	52	36.65	-71.84	7320	168	241	125420	132001		18
	1	0		12	59	30	36.48	-72.05	7320	169	240				
A03	0	2		13	00	58	36.45	-72.09	7320			125950	162601		1
S07	0	1		13	03	30	36.24	-72.38	7320	166	240	130057	166001		18
	1	0		13	05	40	36.11	-72.56	7320	166	240				
	0	0	7′				35.95	-72.78	7320						
	1	0		13	09	28	35.97	-72.87	7320	134	290				
A04	0	2		13	10	00	35.99	-72.91	7320			130848	202301		1
S08	1	1		13	13	50	36.09	-73.21	7320	130	298	131111	208401		18
S09	1	1		13	24	10	36.40	-74.05	6405	143	300	132130	244801		18
A05	0	2	TEMP	13	29	53	36.56	-74.53	6405			132834	284201		1
	1	0		13	33	30	36.75	-74.83	6405	142	309				
S10	0	1		13	34	00	36.78	-74.87	6405	142	309	133115	287001		18
	1	0	8	13	37	43	36.95	-75.14	6405	142	310				
	0	0	TEMP				37.04	-75.28							
	1	0		13	41	45	37.11	-75.48	6405	147	294				
S11	0	1		13	42	06	37.12	-75.50	6405	147	294	133914	327501		18
	1	0		13	44	43	37.18	-75.74	6405						


ROWS S0212_01
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 11.101; md/pd = 218/210
Hs / Tp = 2.14m / 10.86s
2.5
2
1.5
1
0.5
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz
ROWS S0212_02
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 11.97; md/pd = 239/248
Hs / Tp = 2.16m / 9.85s
3
2.5
2
1.5
1
0.5
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz
ROWS S0212_03
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 11.96; md/pd = 174/170
Hs / Tp = 2.14m / 9.85s
2.5
2
1.5
1
0.5
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz

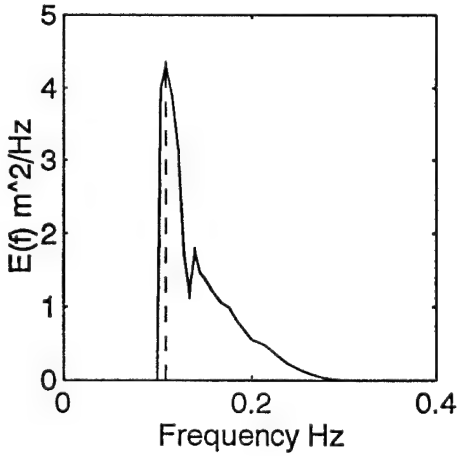


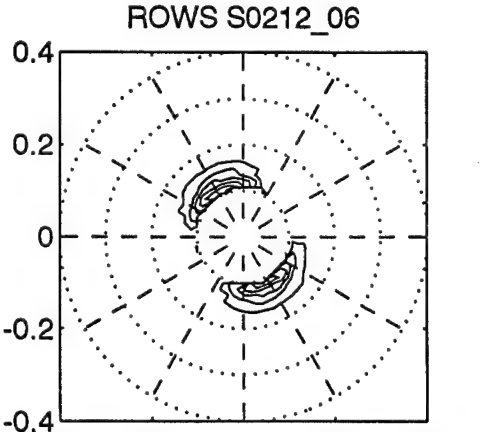
ROWS W = 11.95; md/pd = 118/125



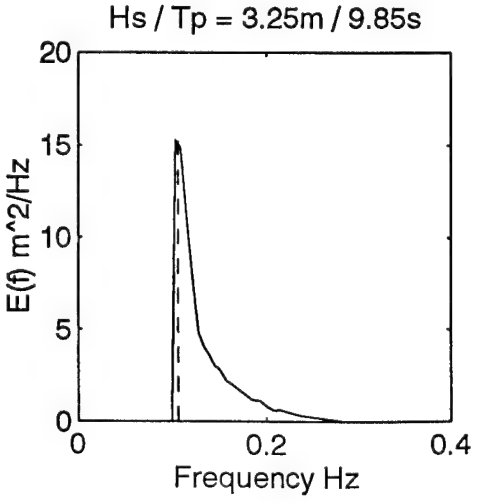


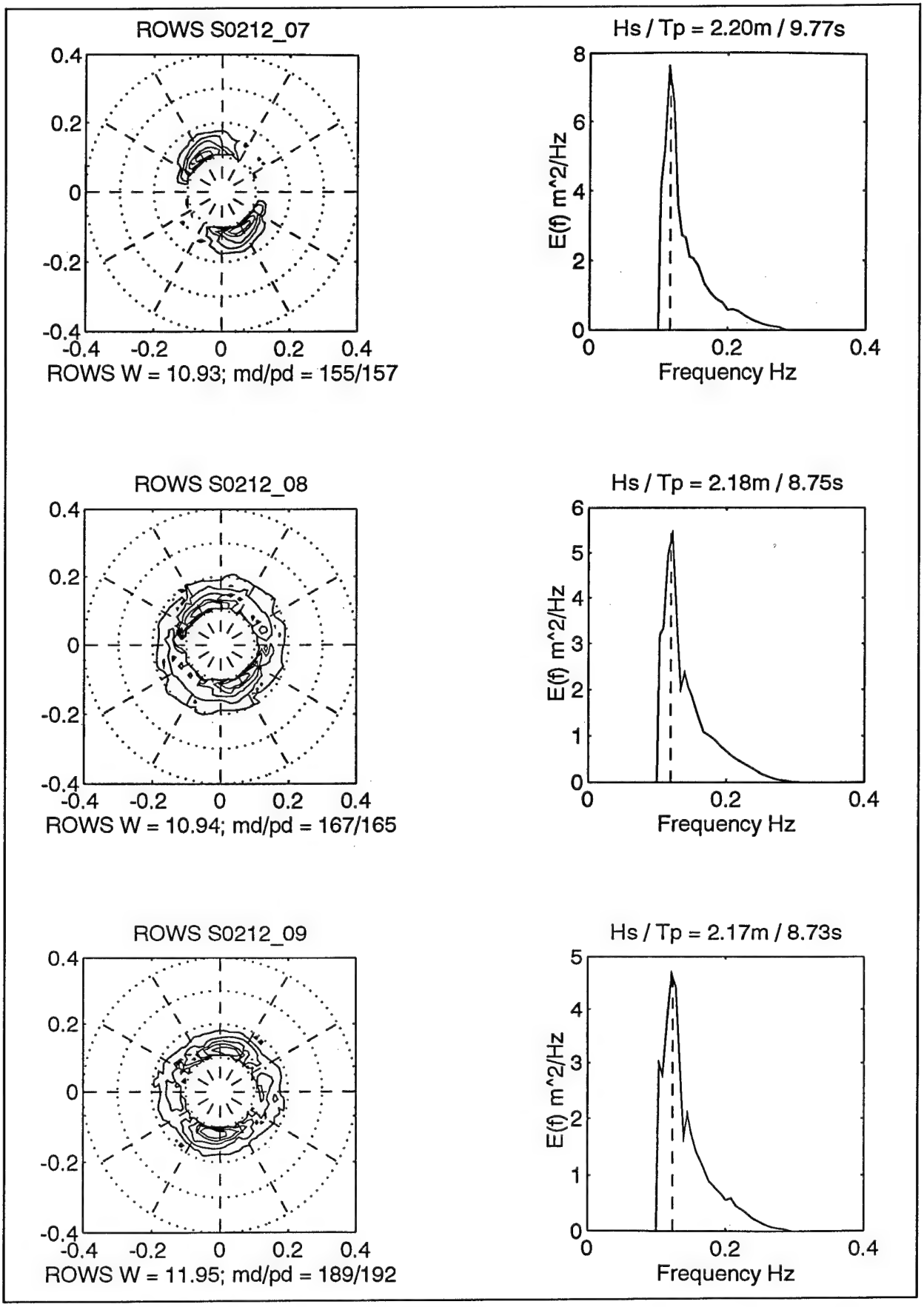
ROWS W = 10.94; md/pd = 152/155

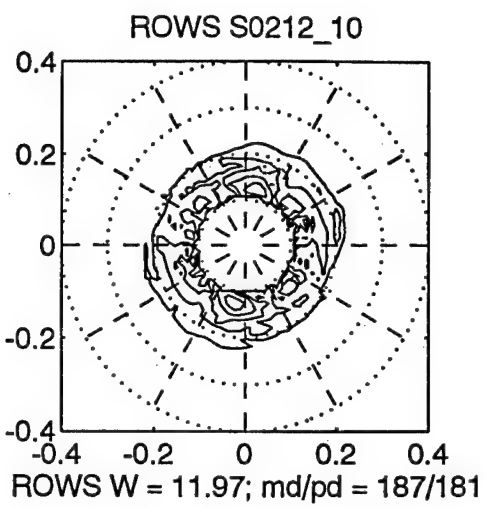


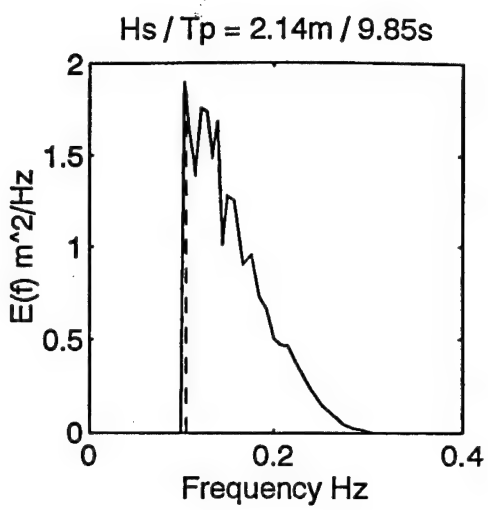


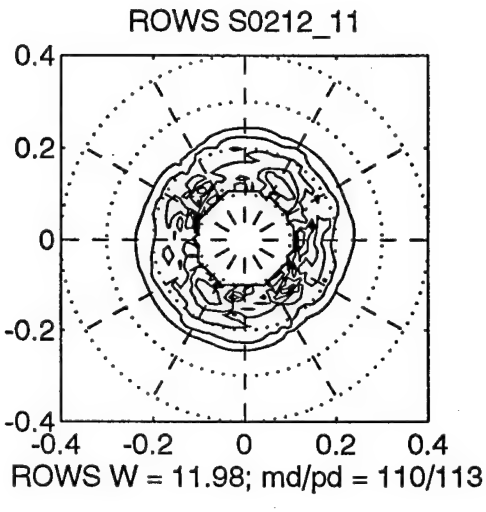
ROWS W = 10.93; md/pd = 150/153

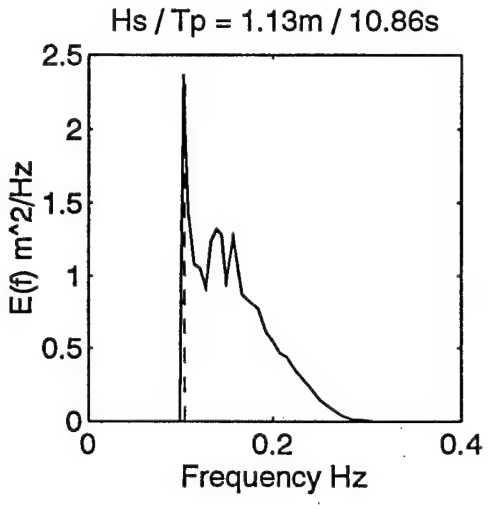



ROWS S0212_07
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 10.93; md/pd = 155/157
Hs / Tp = 2.20m / 9.77s
E(f) m^2/Hz
0 2 4 6 8
0 0.2 0.4
Frequency Hz
ROWS S0212_08
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 10.94; md/pd = 167/165
Hs / Tp = 2.18m / 8.75s
E(f) m^2/Hz
0 1 2 3 4 5 6
0 0.2 0.4
Frequency Hz
ROWS S0212_09
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 11.95; md/pd = 189/192
Hs / Tp = 2.17m / 8.73s
E(f) m^2/Hz
0 1 2 3 4 5
0 0.2 0.4
Frequency Hz


ROWS S0212_10
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 11.97; md/pd = 187/181


Hs / Tp = 2.14m / 9.85s
E(f) m^2/Hz
2
1.5
1
0.5
0
0 0.2 0.4
Frequency Hz


ROWS S0212_11
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 11.98; md/pd = 110/113

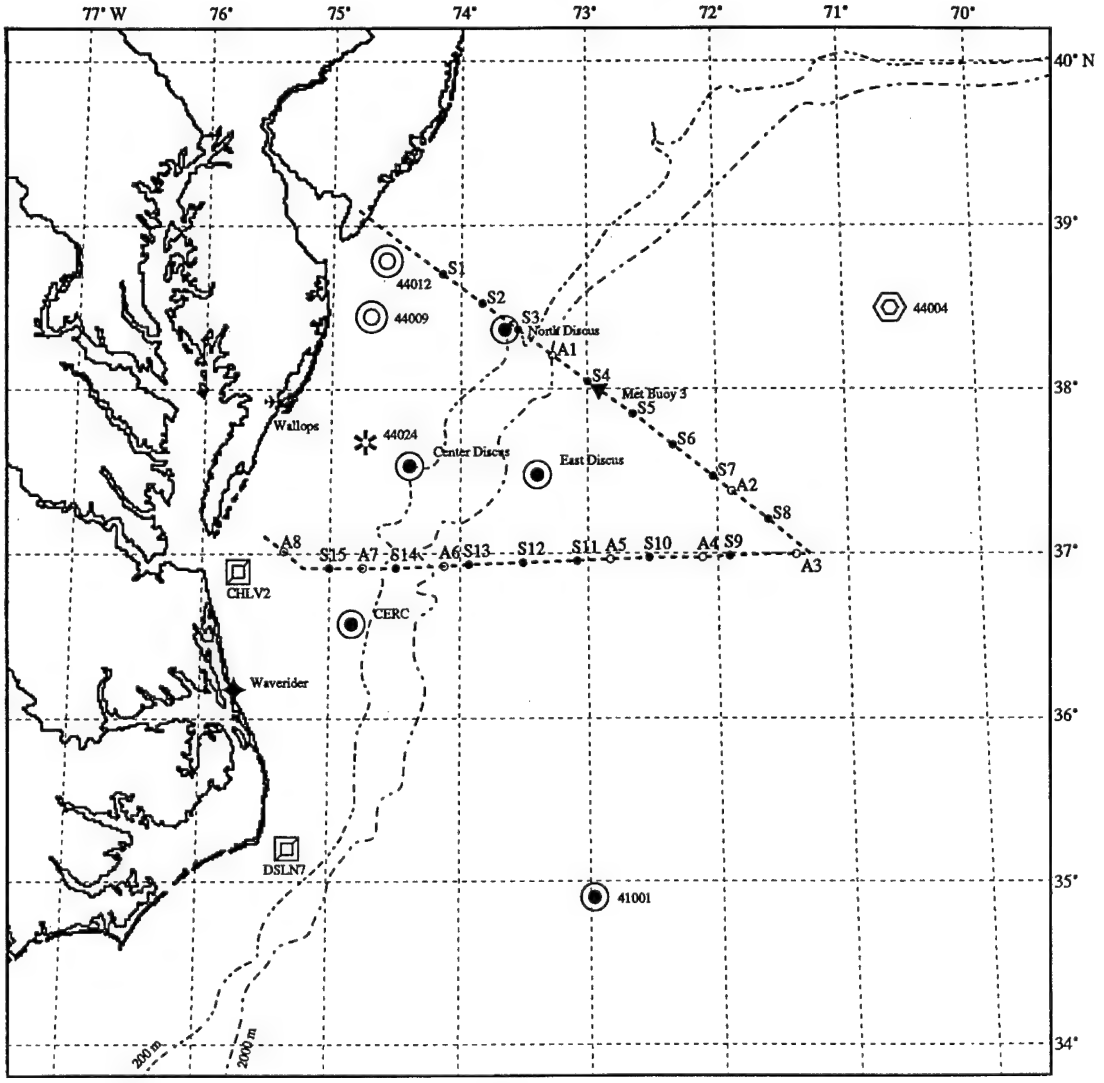

Hs / Tp = 1.13m / 10.86s
E(f) m^2/Hz
2.5
2
1.5
1
0.5
0
0 0.2 0.4
Frequency Hz

Appendix E2: ROWS Spectra and Frequency-Direction Plots for the St. Valentine's Period, 14-16 February 1991

Directional spectra for the four flights of the St. Valentine's observational period are accompanied here by plots of mean direction and directional spreading as functions of (log) frequency.

What are generally the lower of the two sets of curves are the mean directions as given by the first (dotted curve) and second (solid curve) harmonic phase angles; the upper curves are the first and second harmonic directional half power spreads. The vertical dashed line is the nondirectional spectrum peak frequency and the horizontal dashed line is the isotropic limit for the first harmonic directional half-power spread.

ROWS Flight a
14 Feb 1991



Symbols

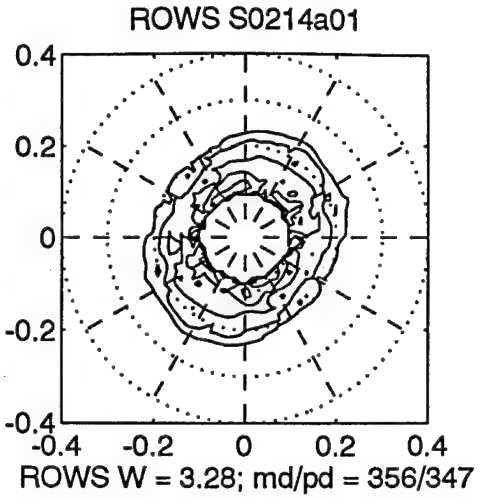
- Coastal Buoy
- 3m Discus Buoy
- 12m Discus Buoy
- 6m NORMAD Buoy
- 1m Met Buoy
- C-Man Station

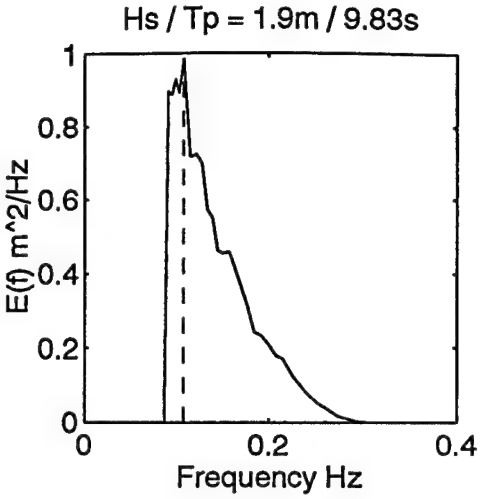
Lambert Conformal Projection
Aug93

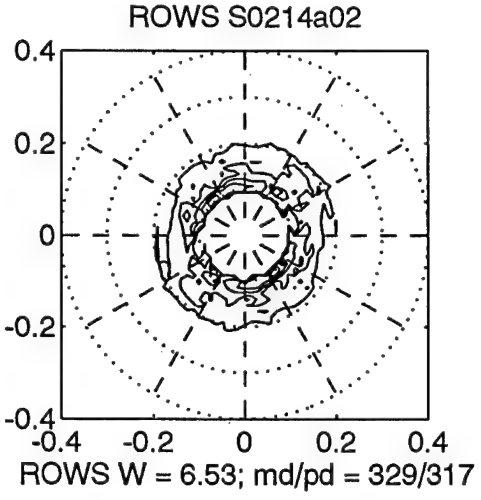
ROWS SWADE FLIGHT NAVIGATION AND FILE DATA
FEB 14, 1991--FLIGHT #1

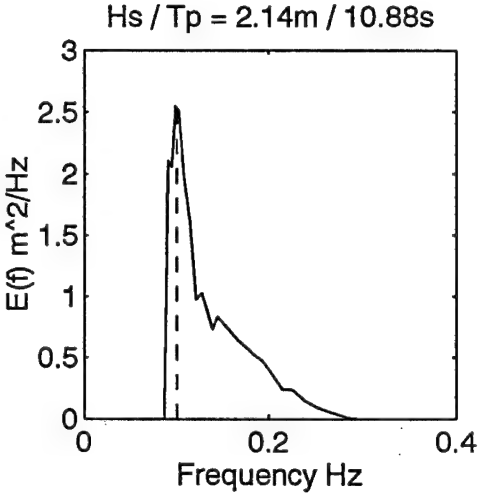
TAPE1/1 FILE	POS FIX	ROWS MODE	BUOY/ WP	EST HH	MM	SS	LAT	LON	ALT	SPD M/S	HDG TRU	PC-TIC START	REC # START	0 DEG DELTA	LEN ME
	1	0	SIE/3				39.09	-74.80	7625						
	[1	0	4	12	57	29	38.82	-74.31	7625]						
S01	1	1		12	59	05	38.71	-74.14	7625	201	140	125913	6001		12
S02	0	1		13	02	15	38.53	-73.83	7625	200	140	130223	25001		12
	1	0	DIS-N	13	04	32	38.40	-73.60	7625	199	140				
S03	0	1		13	05	00	38.37	-73.55	7625	198	140	130504	41001		12
A01	0	2		13	07	31	38.21	-73.28	7625	196	140	130831	56701		1
S04	0	1		13	10	16	38.05	-73.00	7625	194	140	131018	60401		12
S05	0	1		13	13	16	37.85	-72.65	7625	196	140	131318	72401		12
	1	0		13	13	36	37.83	-72.61	7625	196	140				
S06	0	1		13	16	16	37.66	-72.34	7625	196	142	131618	84401		12
S07	0	1		13	19	12	37.47	-72.03	7625	196	144	131912	113701		12
A02	0	2		13	20	45	37.38	-71.89	7625			132143	127301		1
S08	0	1		13	23	16	37.21	-71.61	7625	186	148	132316	153101		12
	[1	0		13	23	33	37.25	-71.59	7652	186	148]				
	1	0	6	13	25	52	37.00	-71.29							
A03	0	2		13	27	30	37.00	-71.38	7625	129	256	132819	153501		2
	1	0		13	29	40	37.00	-71.57	7625	129	256				
S09	0	1		13	33	28	36.99	-71.91	7625	129	255	133248	176701		18
A04	0	2		13	35	51	36.98	-72.12	7625	129	254	133633	196801		2
	1	0		13	37	53	36.98	-72.30	7625	129	254				
S10	0	1		13	40	50	36.98	-72.53	7625	129	254	134005	215701		18
	1	0	7	13	42	30	36.97	-72.67	7625						
A05	0	2		13	44	21	36.97	-72.83	7625	130	256	134456	237801		2
S11	0	1		13	47	20	36.96	-73.09	7625	130	256	134640	243101		18
S12	0	1		13	52	05	36.95	-73.51	7625	130	256	135123	271401		18
S13	0	1		13	56	50	36.94	-73.93	7625	130	256	135607	299701		18
A06	0	2		13	59	00	36.93	-74.12	7625	130	256	135936	318001		2
S14	1	1		14	03	15	36.92	-74.49	7015	128	260	140229	325901		18
A07	0	2		14	06	03	36.92	-74.75	7015			140633	349001		2
S15	0	1		14	08	50	36.92	-75.01	7015	134	260	140754	354401		18
	1	0	8	14	10	57	36.92	-75.21	7015	134	260				
A08	0	2		14	12	40	37.02	-75.36	7015	163	297	141307	381201		2
	1	0		14	14	45	37.11	-75.51	7015	163	297				

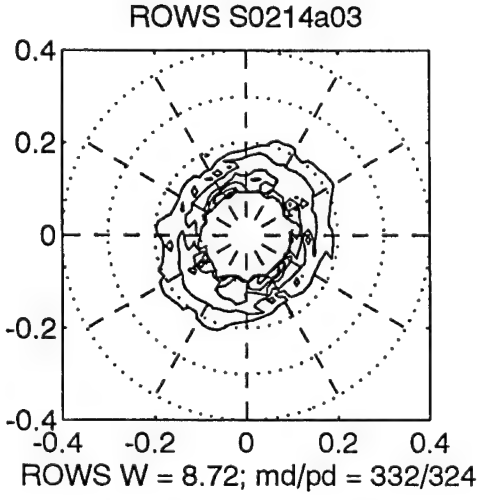
NOTES: (1) HEADINGS BETWEEN 140 AND 148 DEG ON OUTBOUND LEG ARE INTERPOLATED VALUES. ALTHOUGH HEADINGS IN LOG ARE LISTED AS IN DEG TRUE, 140 DEG IS THE MAGNETIC HEADING ACCORDING TO FLIGHT PLAN, AND SO JUST POSSIBLY THIS HEADING MAY BE MAGNETIC RATHER THAN TRUE!

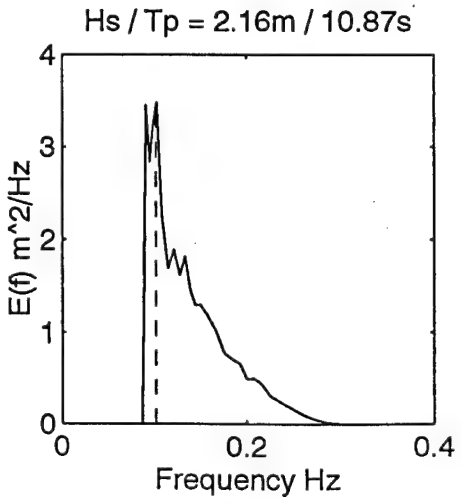

ROWS S0214a01
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 3.28; md/pd = 356/347

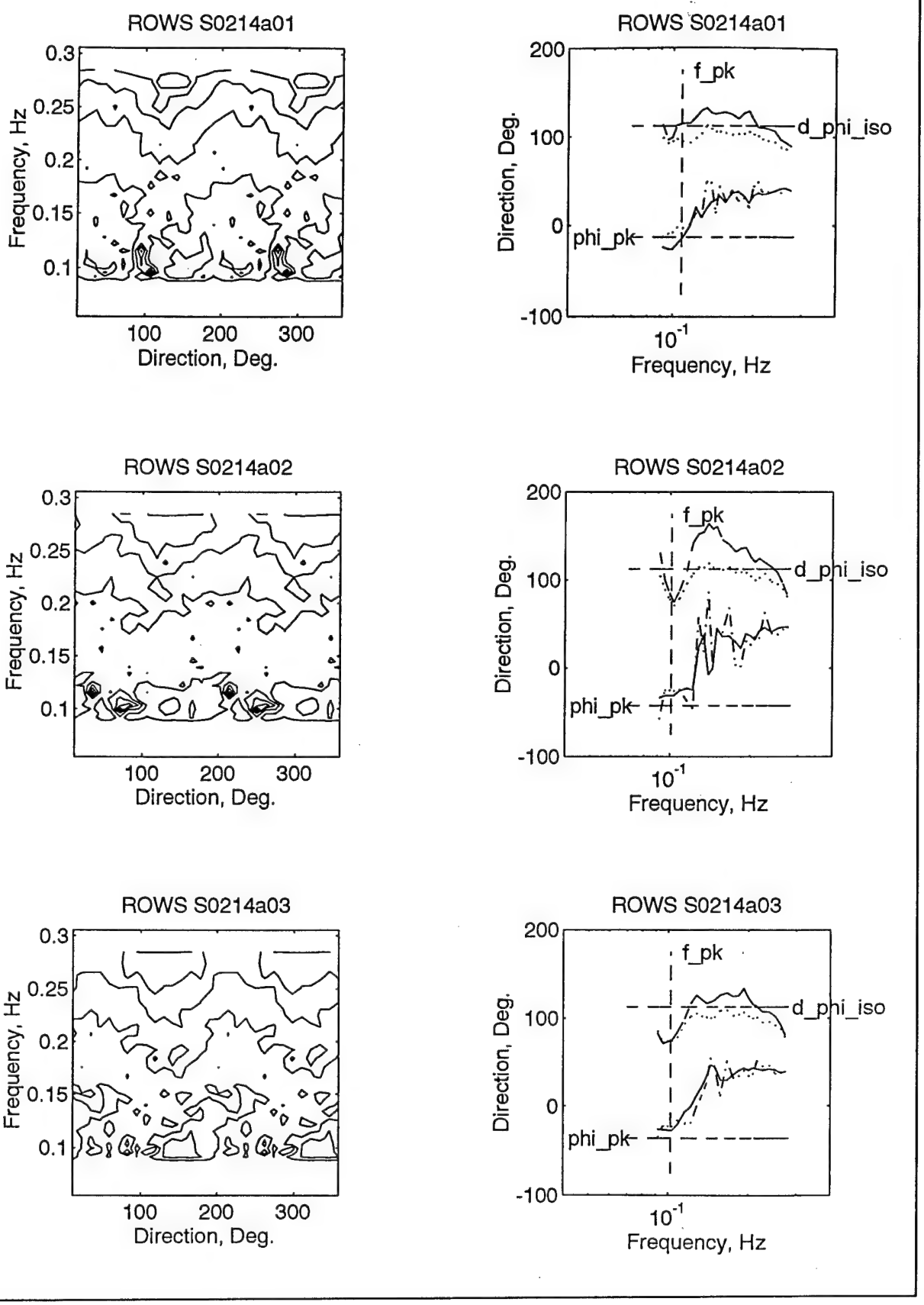

Hs / Tp = 1.9m / 9.83s
E(f) m^2/Hz
1
0.8
0.6
0.4
0.2
0
0 0.2 0.4
Frequency Hz

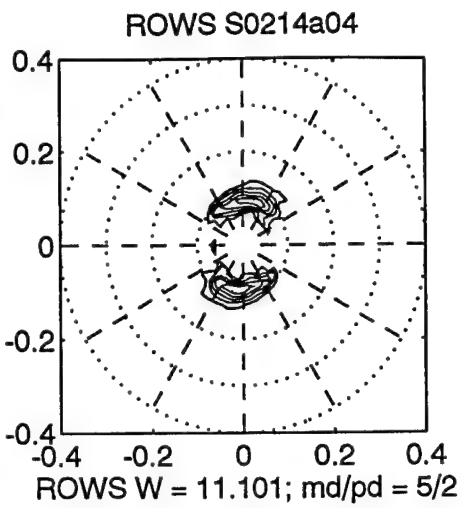

ROWS S0214a02
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 6.53; md/pd = 329/317

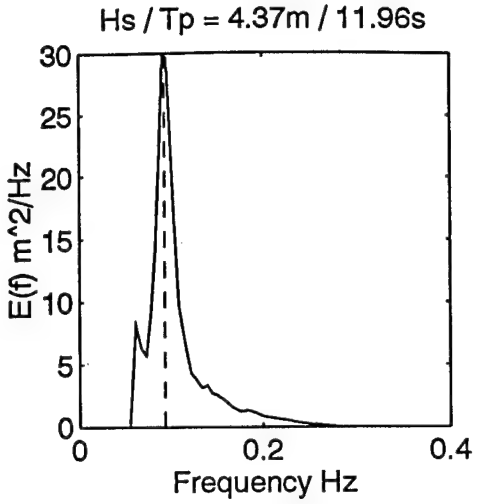

Hs / Tp = 2.14m / 10.88s
E(f) m^2/Hz
3
2.5
2
1.5
1
0.5
0
0 0.2 0.4
Frequency Hz

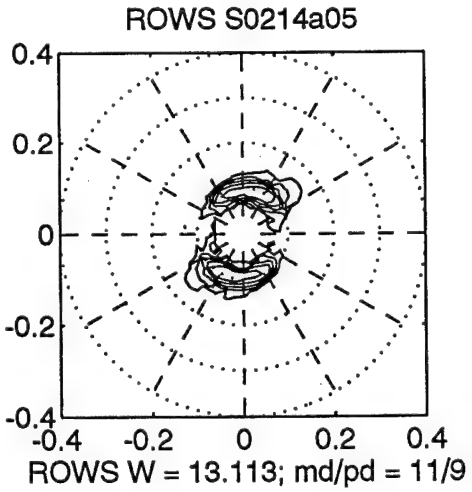

ROWS S0214a03
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 8.72; md/pd = 332/324

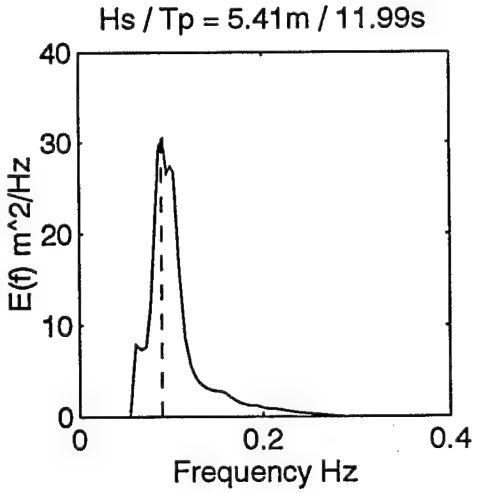

Hs / Tp = 2.16m / 10.87s
E(f) m^2/Hz
4
3
2
1
0
0 0.2 0.4
Frequency Hz

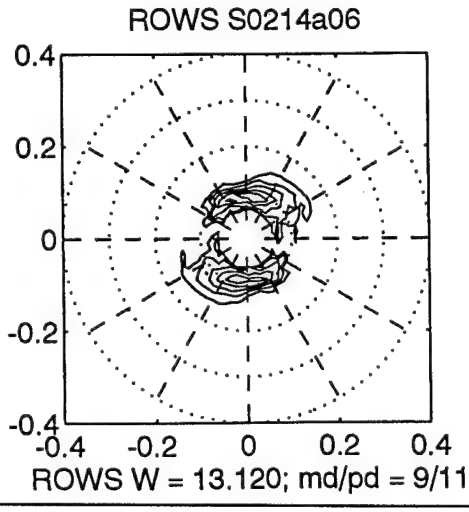

ROWS S0214a01
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.
ROWS S0214a01
Direction, Deg.
200
100
0
-100
f_pk
d_phi_iso
phi_pk
10^{-1}
Frequency, Hz
ROWS S0214a02
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.
ROWS S0214a02
Direction, Deg.
200
100
0
-100
f_pk
d_phi_iso
phi_pk
10^{-1}
Frequency, Hz
ROWS S0214a03
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.
ROWS S0214a03
Direction, Deg.
200
100
0
-100
f_pk
d_phi_iso
phi_pk
10^{-1}
Frequency, Hz

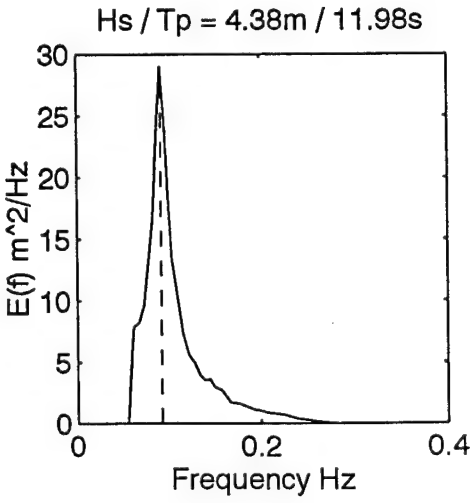

ROWS S0214a04
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 11.101; md/pd = 5/2

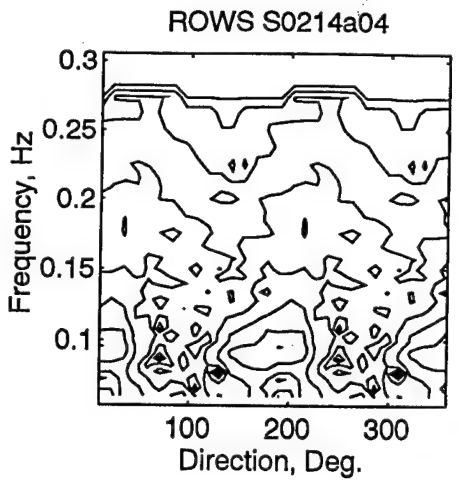

Hs / Tp = 4.37m / 11.96s
E(f) m^2/Hz
30
25
20
15
10
5
0
0 0.2 0.4
Frequency Hz

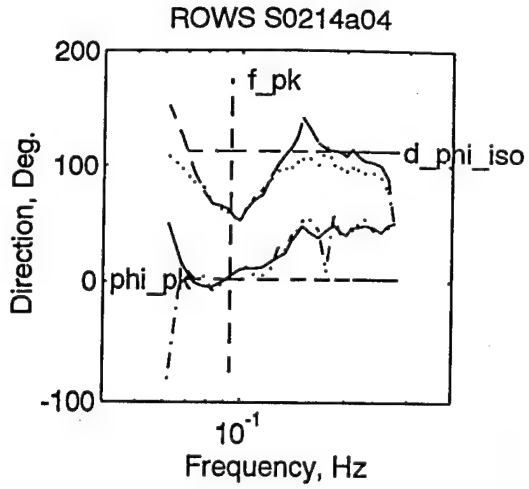

ROWS S0214a05
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 13.113; md/pd = 11/9

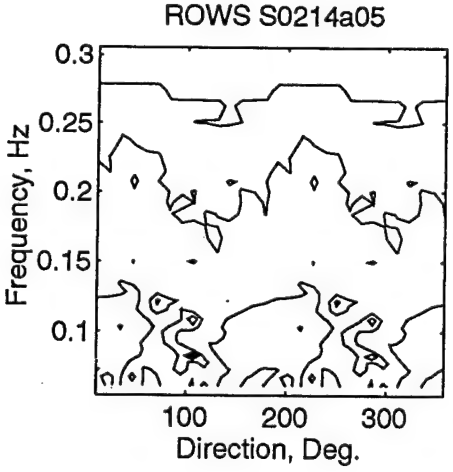

Hs / Tp = 5.41m / 11.99s
E(f) m^2/Hz
40
30
20
10
0
0 0.2 0.4
Frequency Hz

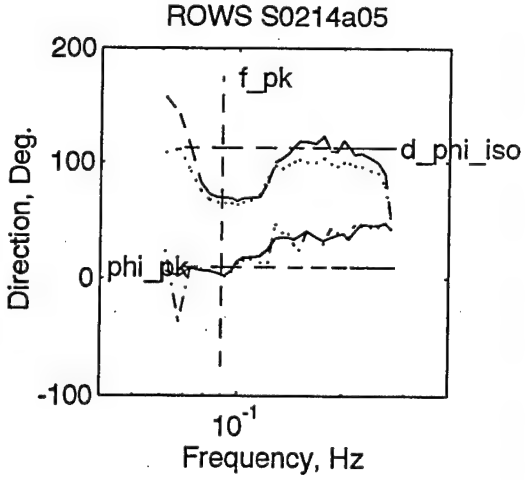

ROWS S0214a06
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 13.120; md/pd = 9/11

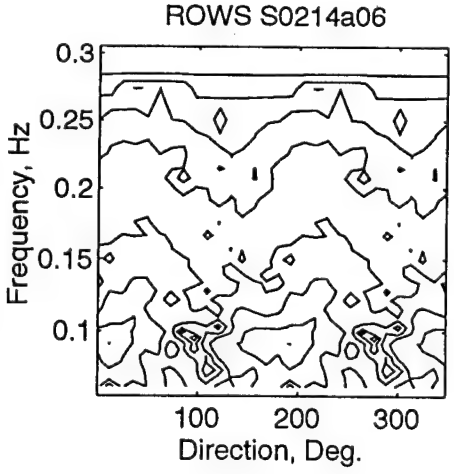

Hs / Tp = 4.38m / 11.98s
E(f) m^2/Hz
30
25
20
15
10
5
0
0 0.2 0.4
Frequency Hz

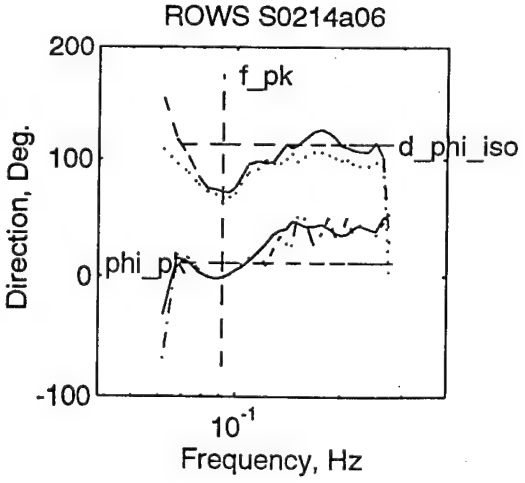

ROWS S0214a04
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

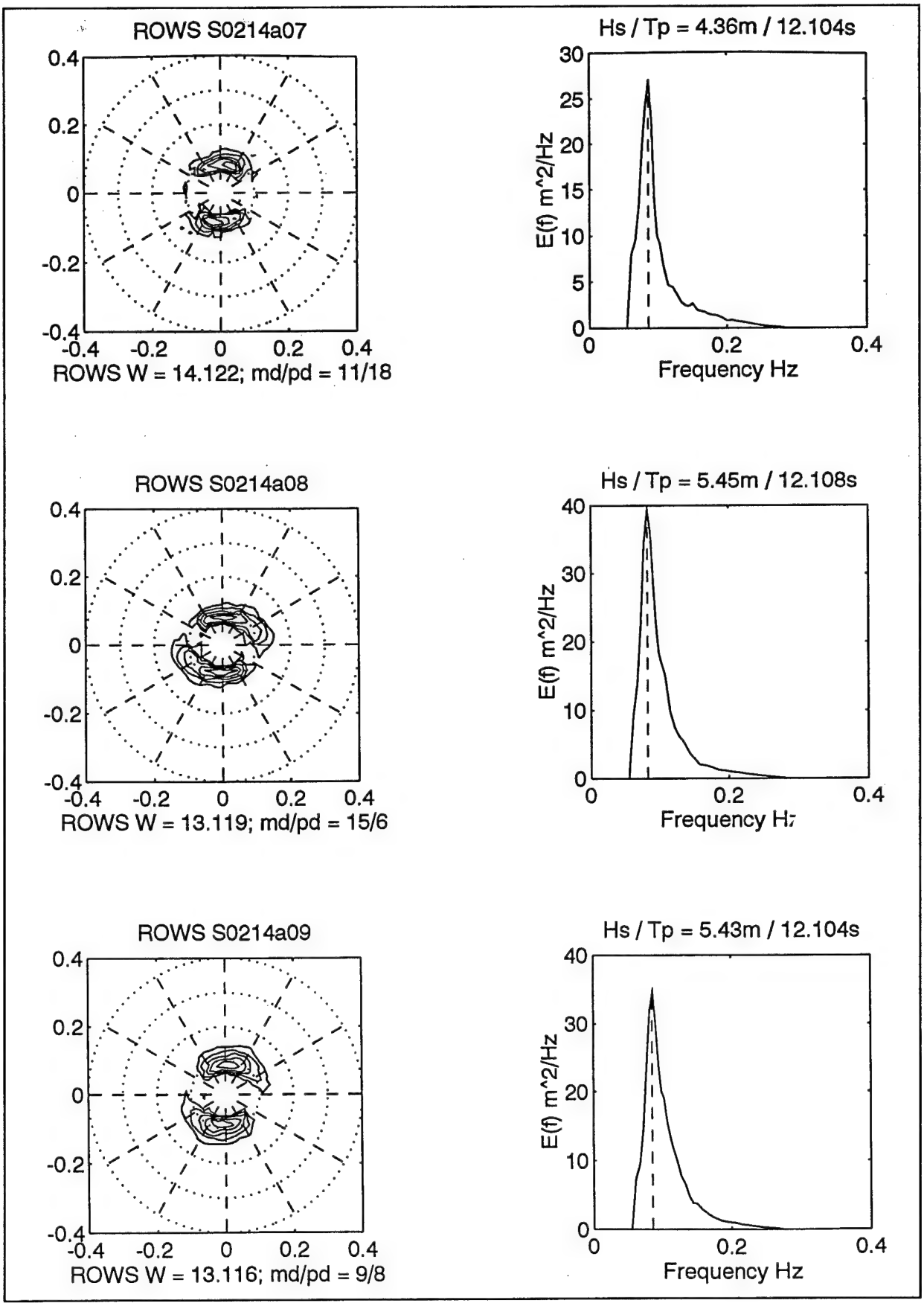

ROWS S0214a04
Direction, Deg.
200
100
0
-100
f_pk
d_phi_iso
phi_pk
10^{-1}
Frequency, Hz

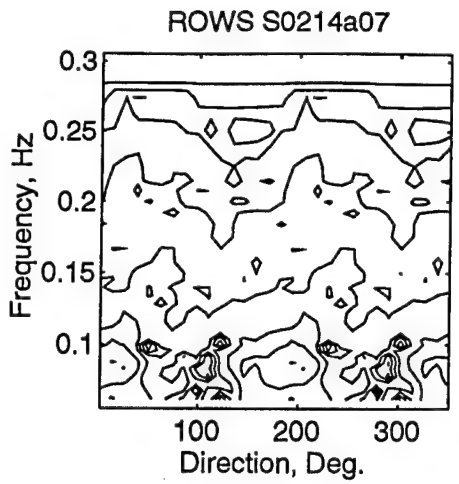

ROWS S0214a05
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

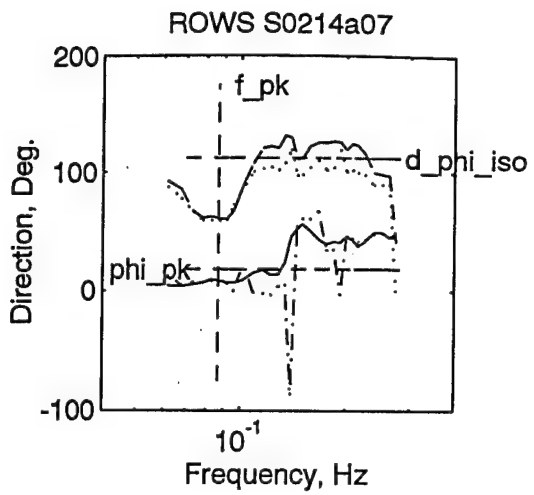

ROWS S0214a05
Direction, Deg.
200
100
0
-100
f_pk
d_phi_iso
phi_pk
10^{-1}
Frequency, Hz

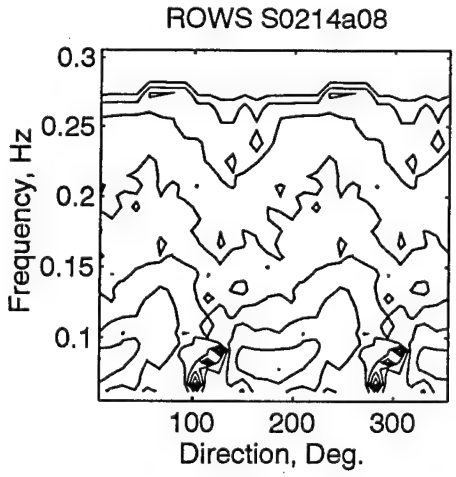

ROWS S0214a06
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

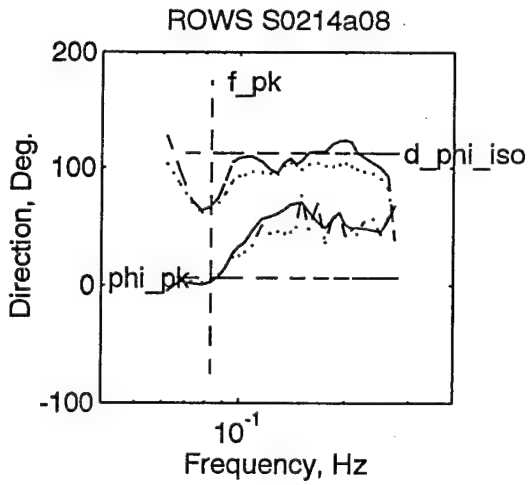

ROWS S0214a06
Direction, Deg.
200
100
0
-100
f_pk
d_phi_iso
phi_pk
10^{-1}
Frequency, Hz

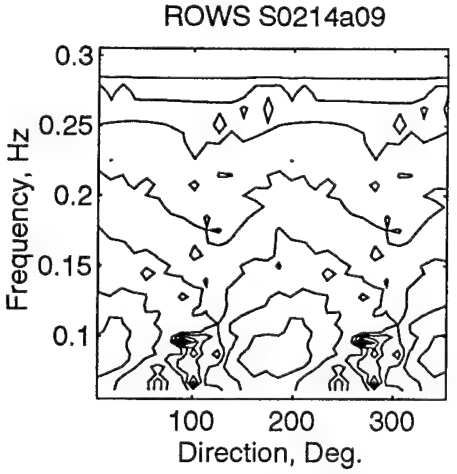

ROWS S0214a07
Hs / Tp = 4.36m / 12.104s
ROWS W = 14.122; md/pd = 11/18
E(f) m^2/Hz
Frequency Hz
ROWS S0214a08
Hs / Tp = 5.45m / 12.108s
ROWS W = 13.119; md/pd = 15/6
E(f) m^2/Hz
Frequency Hz
ROWS S0214a09
Hs / Tp = 5.43m / 12.104s
ROWS W = 13.116; md/pd = 9/8
E(f) m^2/Hz
Frequency Hz

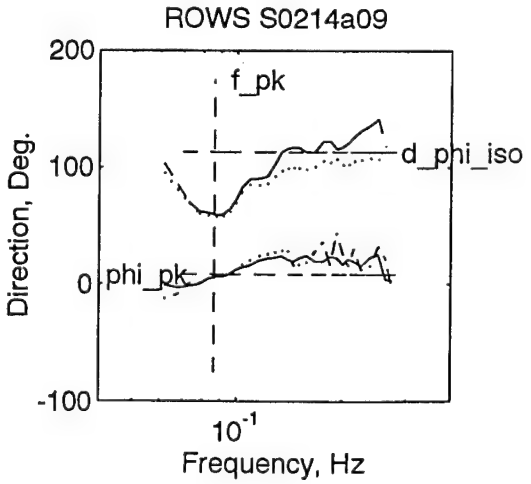

ROWS S0214a07
0.3
0.25
0.2
0.15
0.1
Frequency, Hz
100
200
300
Direction, Deg.

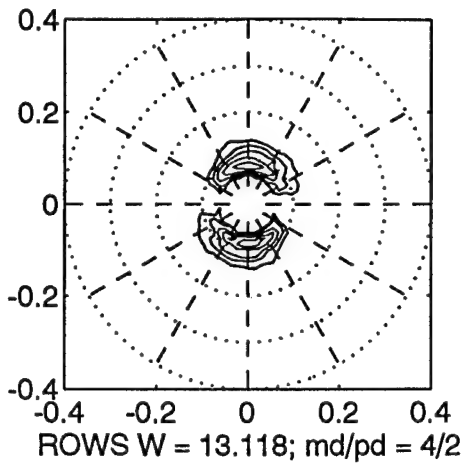

ROWS S0214a07
200
100
0
-100
Direction, Deg.
f_pk
d_phi_iso
phi_pk
10^{-1}
Frequency, Hz

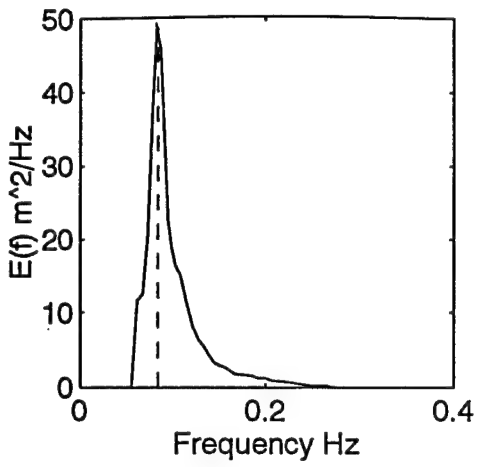

ROWS S0214a08
0.3
0.25
0.2
0.15
0.1
Frequency, Hz
100
200
300
Direction, Deg.

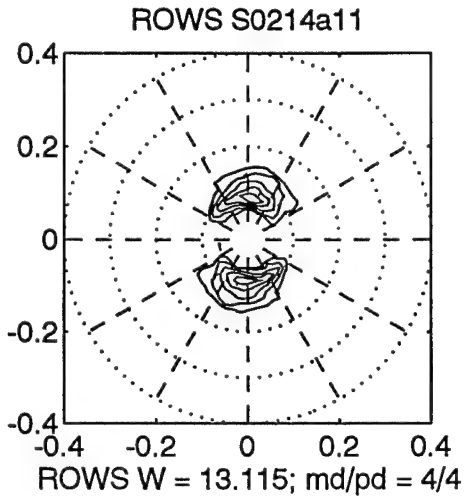

ROWS S0214a08
200
100
0
-100
Direction, Deg.
f_pk
d_phi_iso
phi_pk
10^{-1}
Frequency, Hz

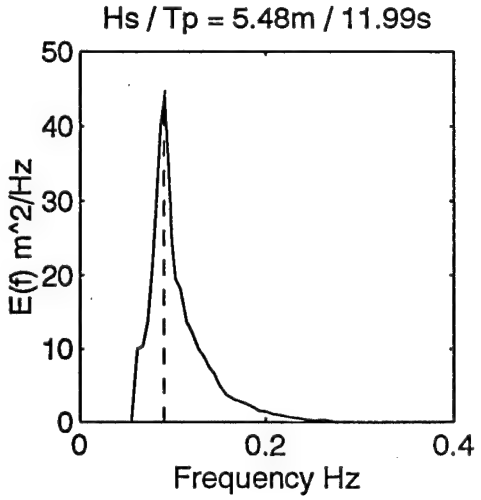

ROWS S0214a09
0.3
0.25
0.2
0.15
0.1
Frequency, Hz
100
200
300
Direction, Deg.

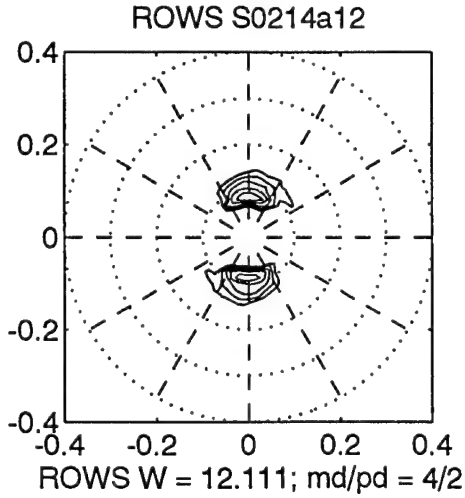

ROWS S0214a09
200
100
0
-100
Direction, Deg.
f_pk
d_phi_iso
phi_pk
10^{-1}
Frequency, Hz

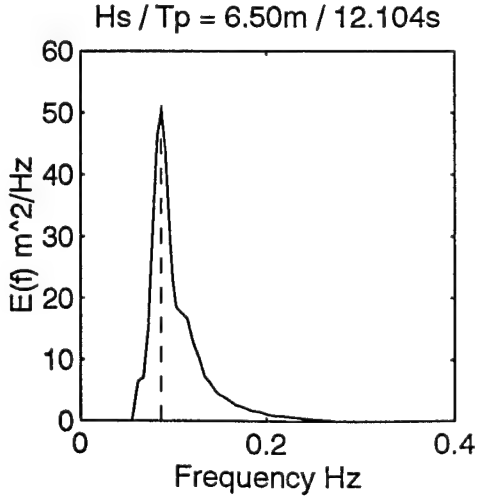

ROWS S0214a10
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 13.118; md/pd = 4/2

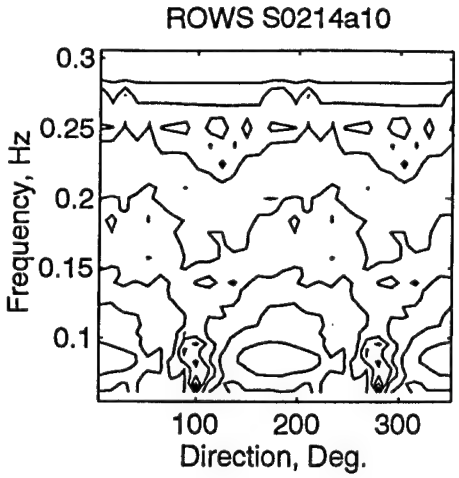

Hs / Tp = 5.47m / 12.106s
50
40
30
20
10
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz

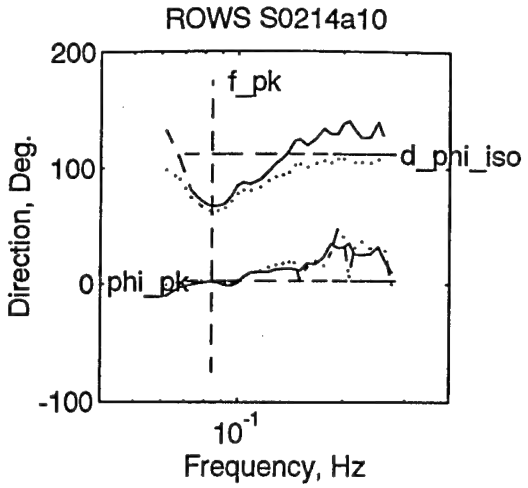

ROWS S0214a11
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 13.115; md/pd = 4/4

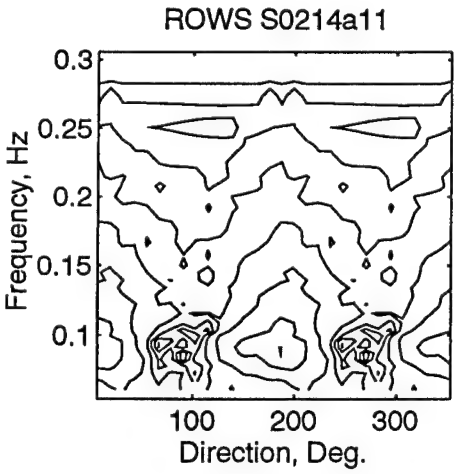

Hs / Tp = 5.48m / 11.99s
50
40
30
20
10
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz

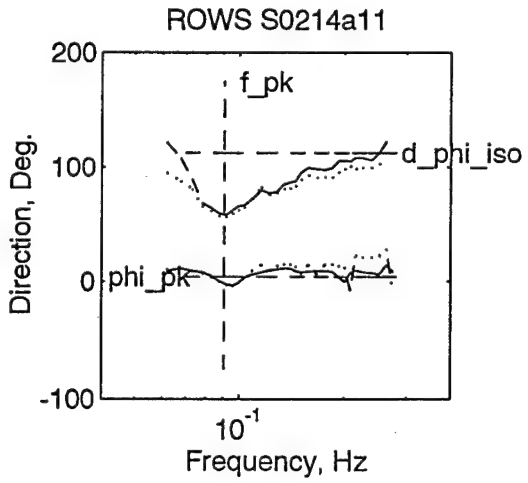

ROWS S0214a12
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 12.111; md/pd = 4/2

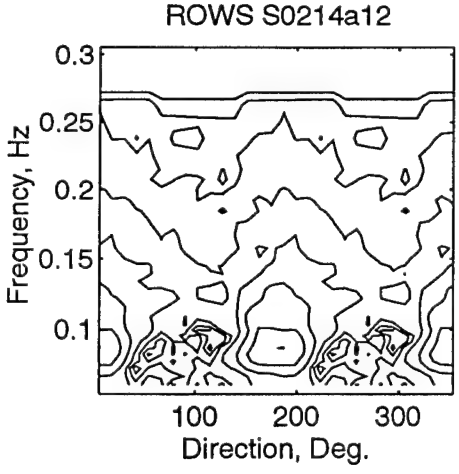

Hs / Tp = 6.50m / 12.104s
60
50
40
30
20
10
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz

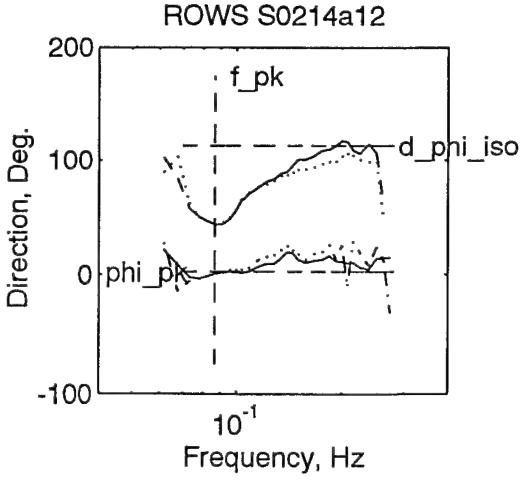

ROWS S0214a10
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

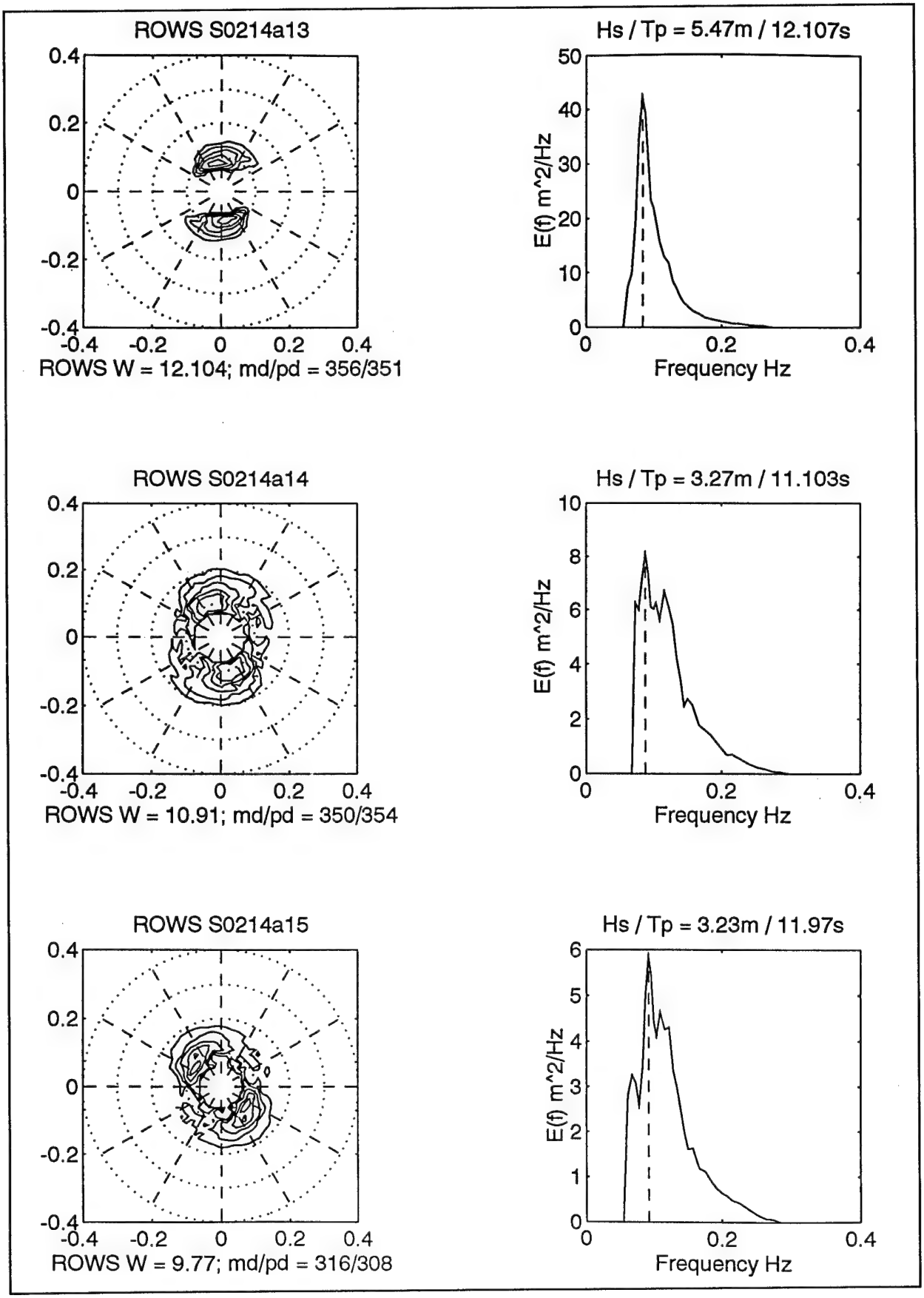

ROWS S0214a10
Direction, Deg.
200
100
0
-100
f_pk
d_phi_iso
phi_pk
10^{-1}
Frequency, Hz

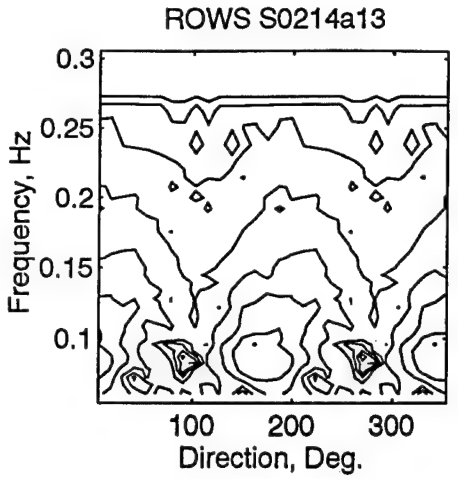

ROWS S0214a11
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

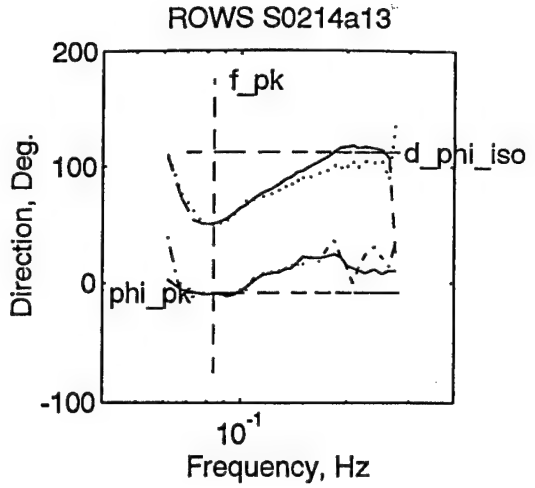

ROWS S0214a11
Direction, Deg.
200
100
0
-100
f_pk
d_phi_iso
phi_pk
10^{-1}
Frequency, Hz

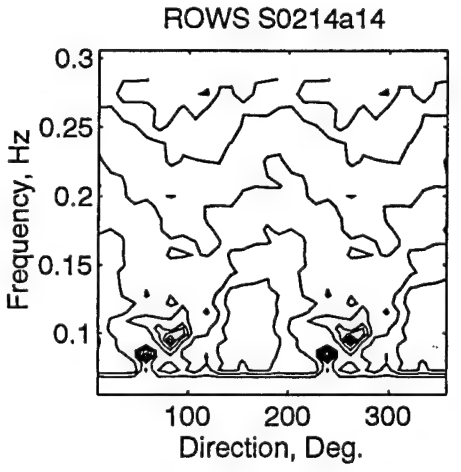

ROWS S0214a12
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

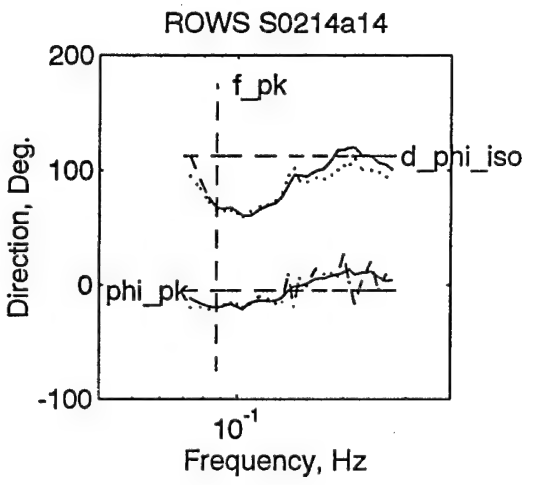

ROWS S0214a12
Direction, Deg.
200
100
0
-100
f_pk
d_phi_iso
phi_pk
10^{-1}
Frequency, Hz

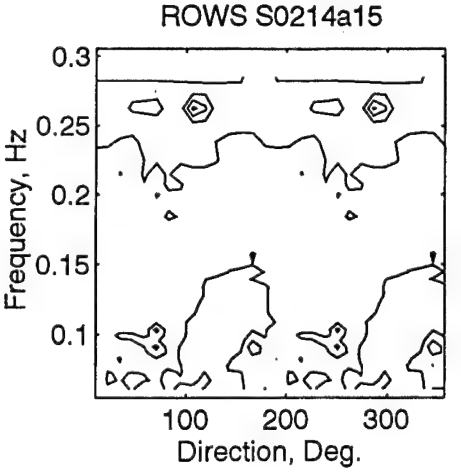

ROWS S0214a13
Hs / Tp = 5.47m / 12.107s
ROWS W = 12.104; md/pd = 356/351
E(f) m^2/Hz
Frequency Hz
ROWS S0214a14
Hs / Tp = 3.27m / 11.103s
ROWS W = 10.91; md/pd = 350/354
E(f) m^2/Hz
Frequency Hz
ROWS S0214a15
Hs / Tp = 3.23m / 11.97s
ROWS W = 9.77; md/pd = 316/308
E(f) m^2/Hz
Frequency Hz

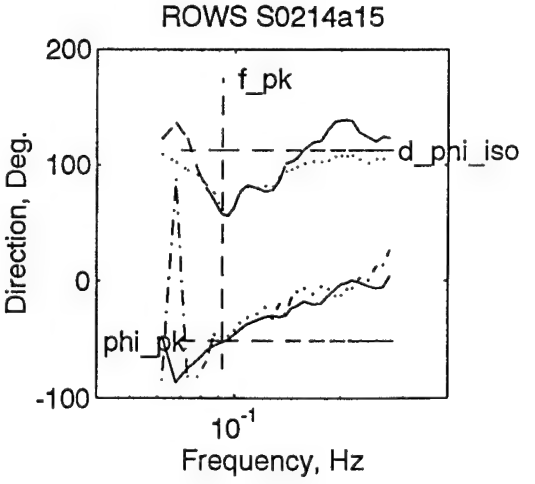

ROWS S0214a13
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

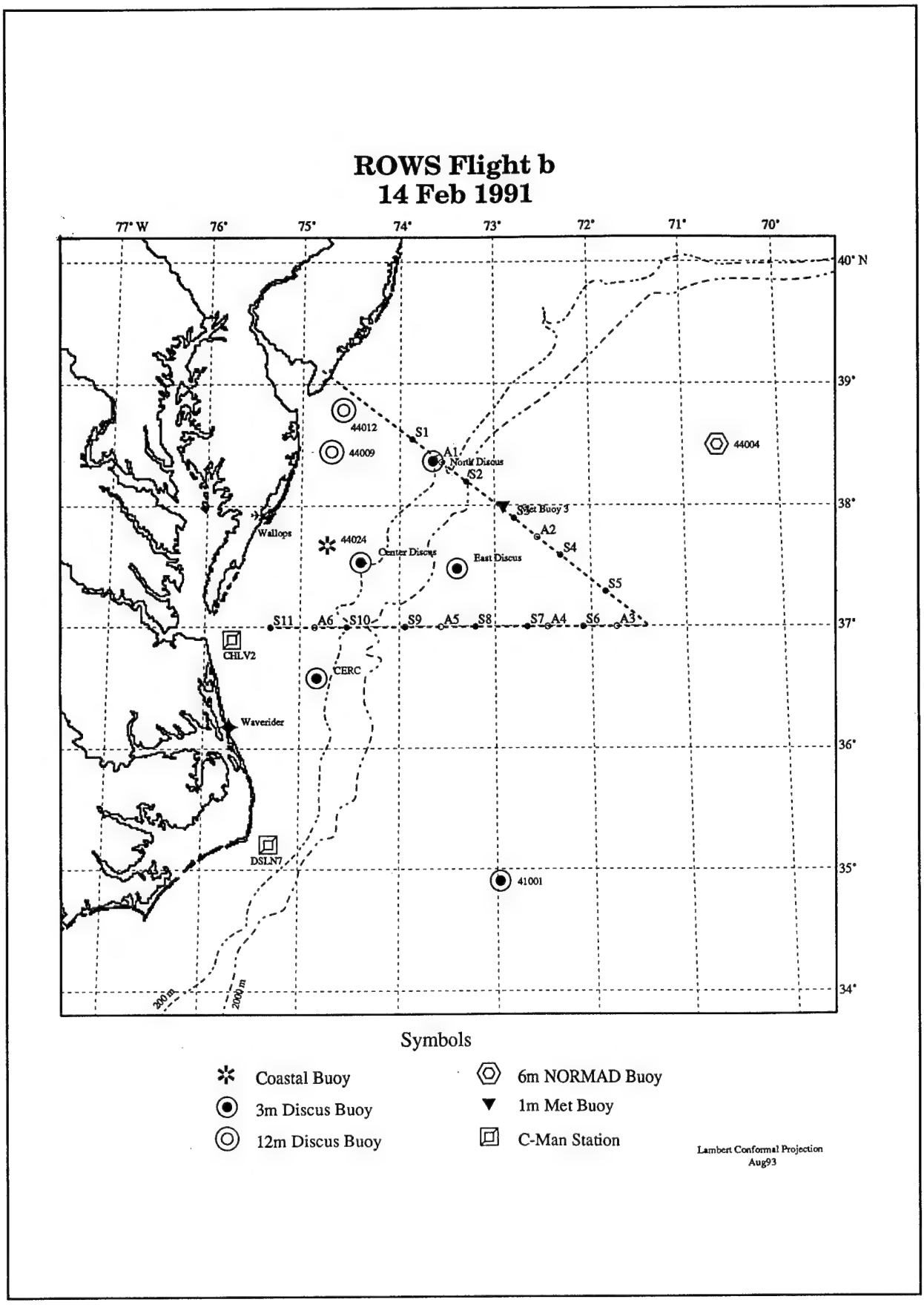

ROWS S0214a13
Direction, Deg.
200
100
0
-100
f_pk
d_phi_iso
phi_pk
10^{-1}
Frequency, Hz


ROWS S0214a14
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.


ROWS S0214a14
Direction, Deg.
200
100
0
-100
f_pk
d_phi_iso
phi_pk
10^{-1}
Frequency, Hz


ROWS S0214a15
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

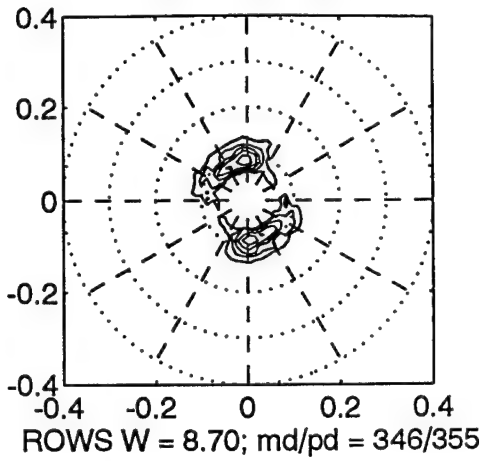

ROWS S0214a15
Direction, Deg.
200
100
0
-100
f_pk
d_phi_iso
phi_pk
10^{-1}
Frequency, Hz


ROWS Flight b
14 Feb 1991
77° W
76°
75°
74°
73°
72°
71°
70°
40° N
39°
38°
37°
36°
35°
34°
44012
44009
44004
S1
A1
North Discus
S2
Met Buoy 3
A2
S4
S5
44024
Center Discus
East Discus
Wallops
S11
A6
S10
S9
A5
S8
S7
A4
S6
A3
CHLV2
CERC
Waverider
DSLN7
41001
200 m
2000 m
Symbols
Coastal Buoy
3m Discus Buoy
12m Discus Buoy
6m NORMAD Buoy
1m Met Buoy
C-Man Station
Lambert Conformal Projection
Aug93

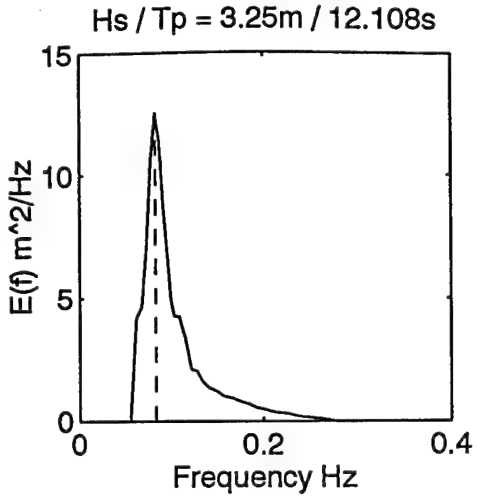
ROWS SWADE FLIGHT NAVIGATION AND FILE DATA
FEB 14, 1991--FLIGHT #2

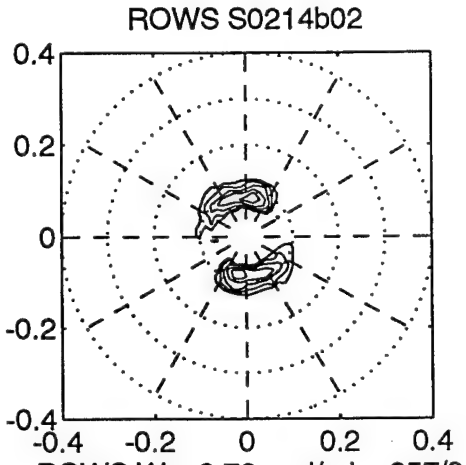
TAPE1/1 FILE	POS FIX	ROWS MODE	BUOY/ WP	EST HH	MM	SS	LAT	LON	ALT	SPD M/S	HDG TRU	PC-TIC START	REC # START	0 DEG DELTA	LEN ME
	1	0	SIE/3	20	28	00	39.11	-74.80							
S01	1	1		20	37	50	38.55	-73.87	7625	192	138	203723	28401		12
A01	0	2		20	41	10	38.36	-73.56	7625			204103	23901		1
S02	0	1		20	43	50	38.20	-73.30	7625	173	152	204243	32101		12
	1	0		20	44	16	38.17	-73.24	7625	173	152				
S03	0	1		20	49	00	37.90	-72.80	7625	173	151	204852	69001		12
A02	0	2		20	51	40	37.74	-72.56	7625	174	150	205106	79401		2
S04	0	1		20	54	22	37.59	-72.32	7625	174	150	205311	85501		12
S05	0	1		20	59	30	37.29	-71.85	7625	174	157	205819	116301		12
	1	0		21	02	45	37.11	-71.56	7625	174	157				
	1	0	6	21	03	35	37.00	-71.40	7625						
A03	0	2		21	06	24	37.00	-71.74	7625	126	250	210603	151801		2
	1	0		21	09	30	37.00	-72.01	7625	126	250				
S06	0	1		21	10	22	37.00	-72.09	7625	126	250	210834	163801		18
A04	0	2		21	14	23	37.00	-72.46	7625	126	250	211356	193801		2
S07	1	1	7	21	16	35	37.00	-72.67	7625	126	250	211518	199901		12
S08	0	1		21	21	53	37.00	-73.21	7625	126	250	212030	231301		12
A05	0	2		21	25	22	37.00	-73.57	7015	156	249	212440	244401		2
S09	1	1		21	28	59	37.00	-73.94	7015	156	249	212733	253801		12
S10	0	1		21	34	10	37.00	-74.53	7015	156	249	213242	284701		12
A06	0	2		21	37	02	37.00	-74.86	7015	156	249	213625	301801		2
	1	0		21	40	24	37.00	-75.25	7015	165	254				
S11	0	1		21	41	03	37.00	-75.31	7015	165	254	213904	314101		18

NOTES: (1) S05 HEADING MAY BE IN ERROR. (2) SOME POSITION DATA ON OUTBOUND LEG (OMITTED SINCE WE USE INTERPOLATION BETWEEN 20:44:16 AND 21:02:45 POSTION FIXES.

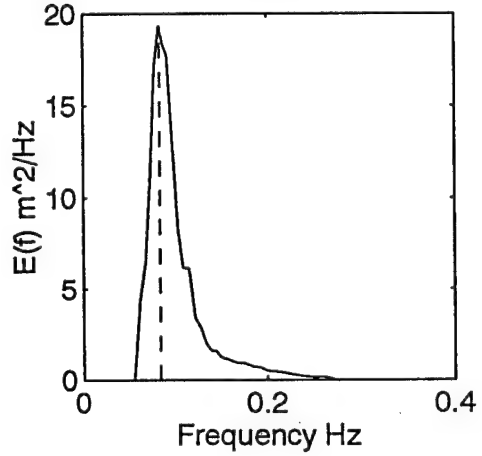


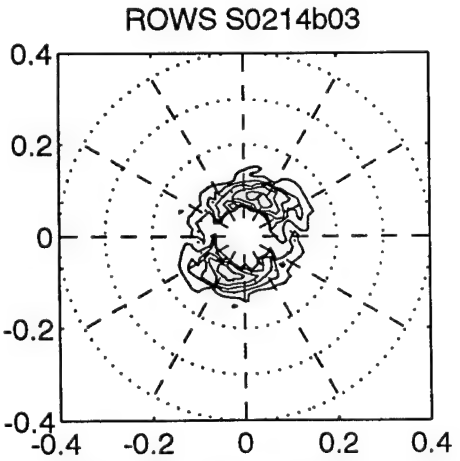
ROWS W = 8.70; md/pd = 346/355



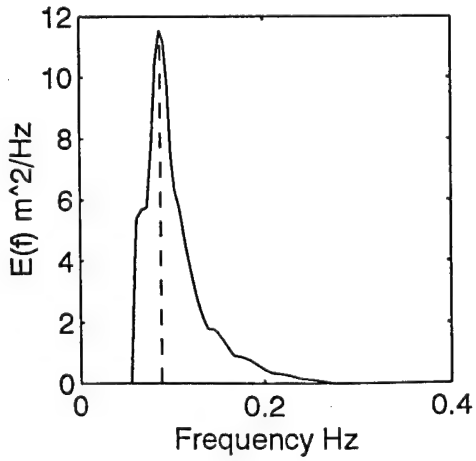


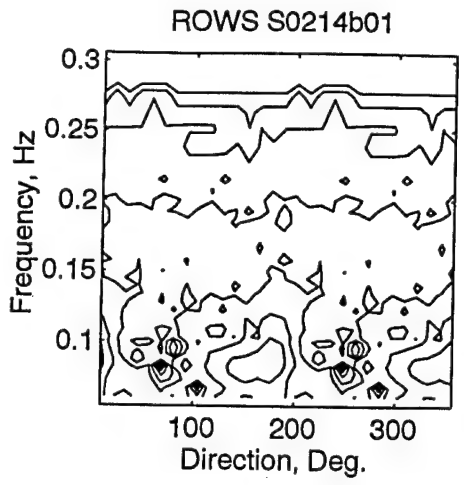
ROWS W = 8.76; md/pd = 357/9

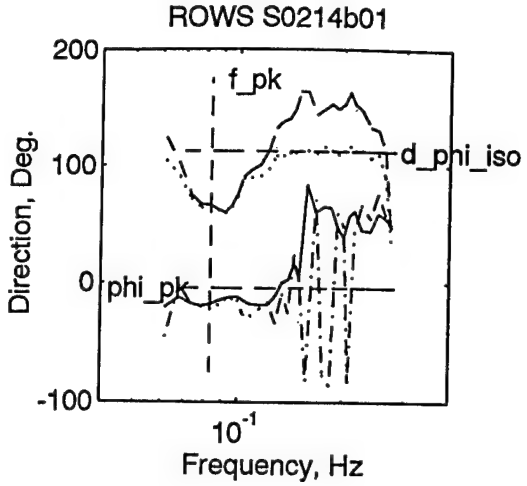


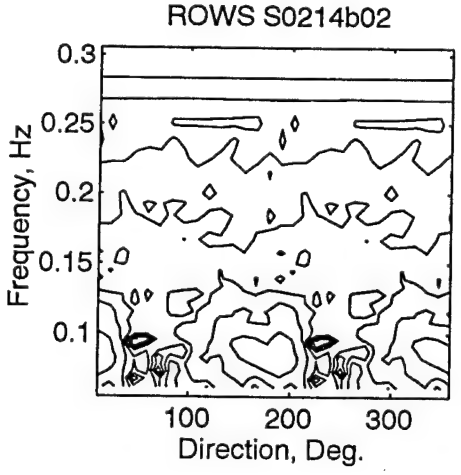


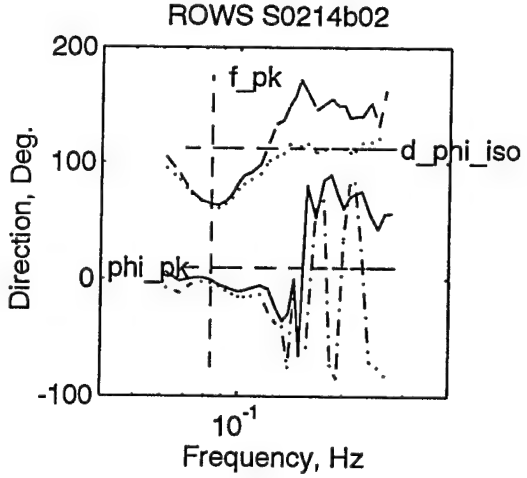
ROWS W = 9.80; md/pd = 23/32

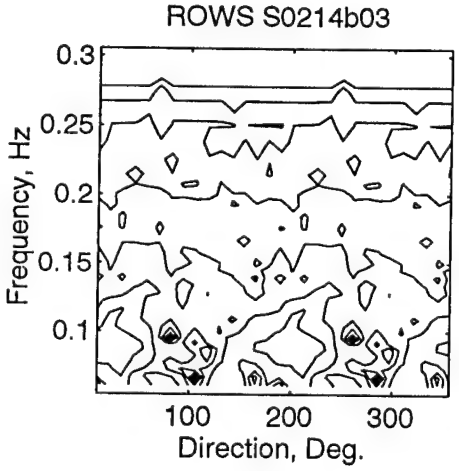


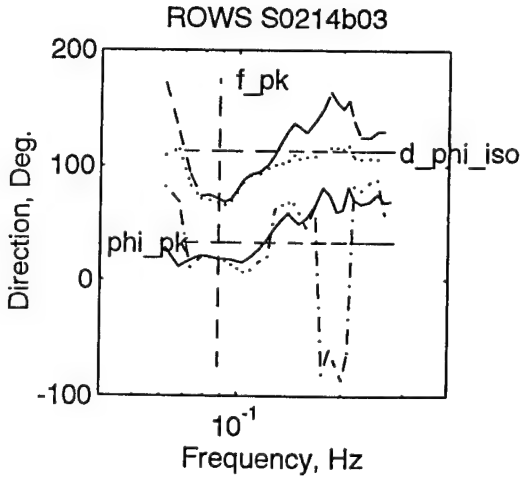

ROWS S0214b01
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

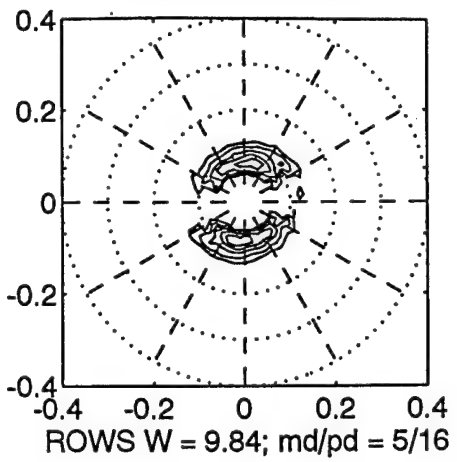

ROWS S0214b01
Direction, Deg.
200
100
0
-100
f_pk
d_phi_iso
phi_pk
10^{-1}
Frequency, Hz

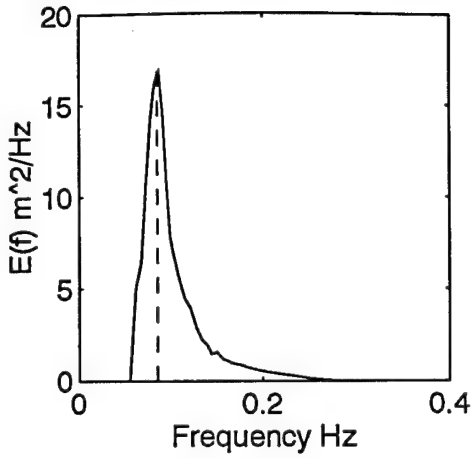

ROWS S0214b02
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

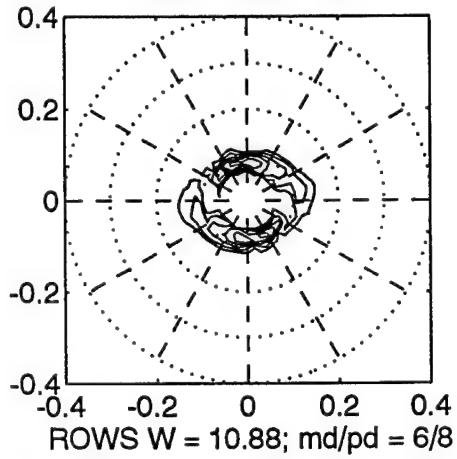

ROWS S0214b02
Direction, Deg.
200
100
0
-100
f_pk
d_phi_iso
phi_pk
10^{-1}
Frequency, Hz

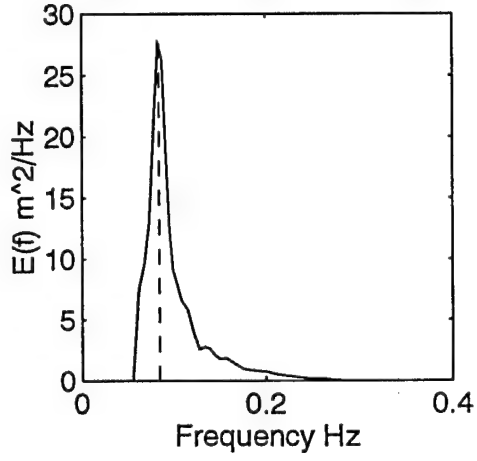

ROWS S0214b03
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

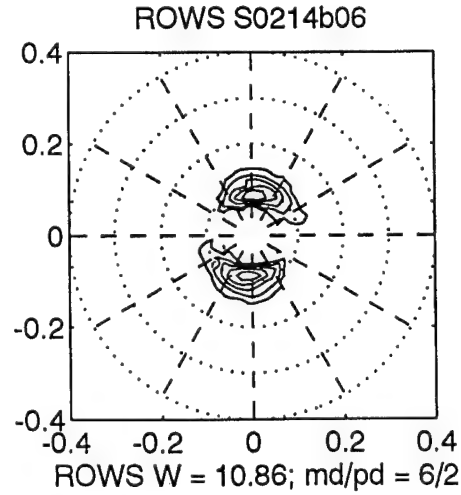

ROWS S0214b03
Direction, Deg.
200
100
0
-100
f_pk
d_phi_iso
phi_pk
10^{-1}
Frequency, Hz

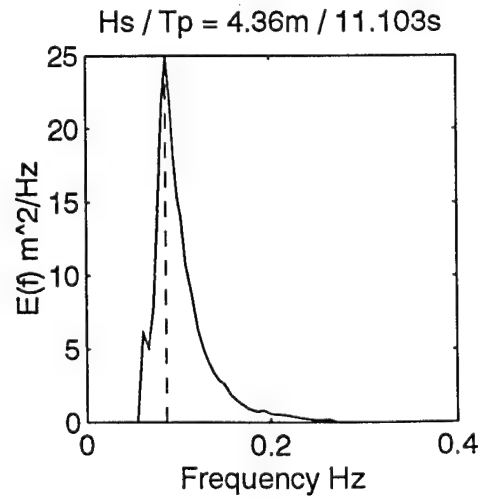

ROWS S0214b04
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 9.84; md/pd = 5/16

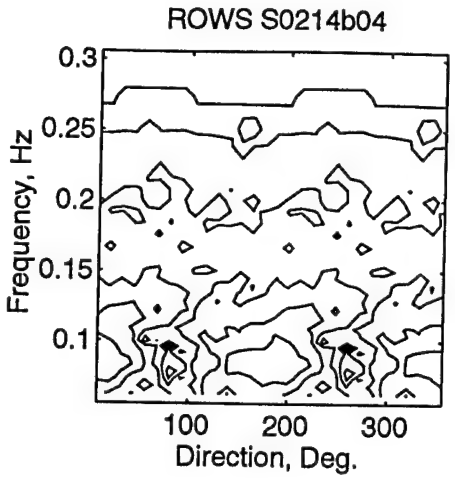

Hs / Tp = 3.30m / 12.104s
E(f) m^2/Hz
20
15
10
5
0
0 0.2 0.4
Frequency Hz

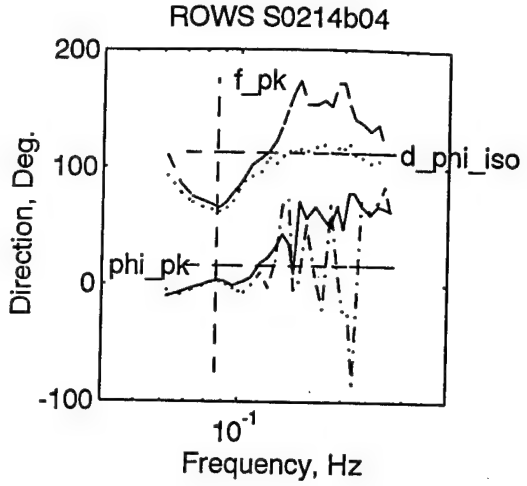

ROWS S0214b05
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 10.88; md/pd = 6/8

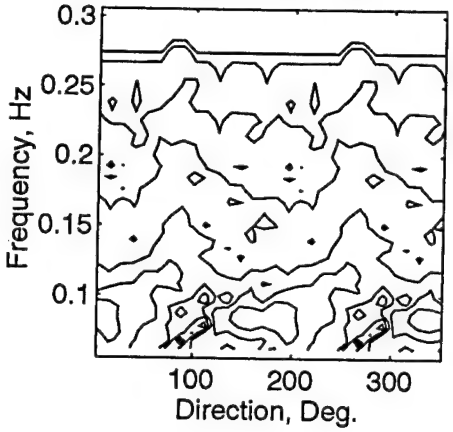

Hs / Tp = 4.35m / 12.106s
E(f) m^2/Hz
30
25
20
15
10
5
0
0 0.2 0.4
Frequency Hz

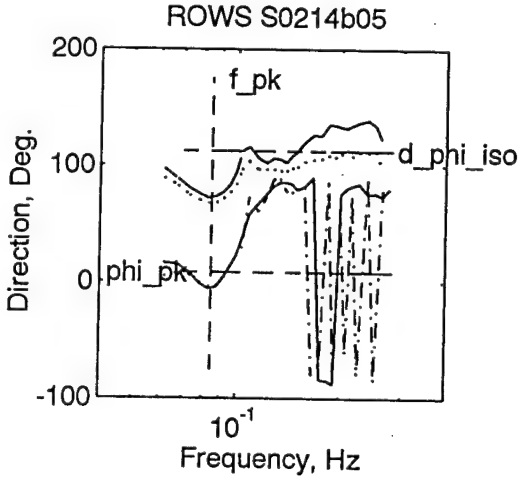

ROWS S0214b06
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 10.86; md/pd = 6/2

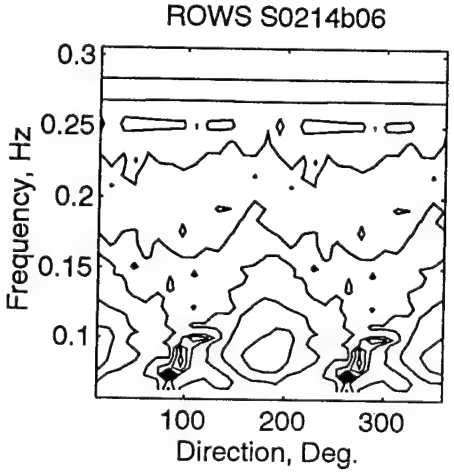

Hs / Tp = 4.36m / 11.103s
E(f) m^2/Hz
25
20
15
10
5
0
0 0.2 0.4
Frequency Hz

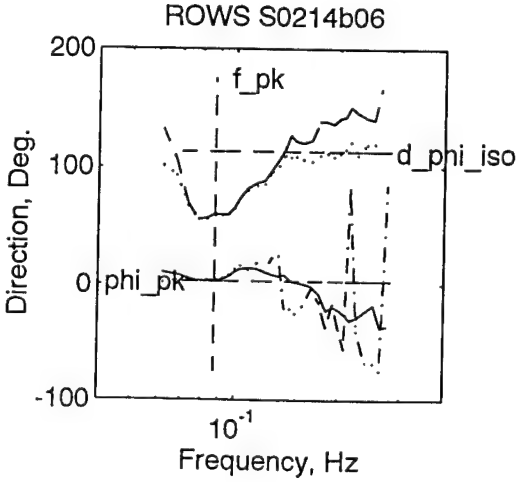

ROWS S0214b04
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

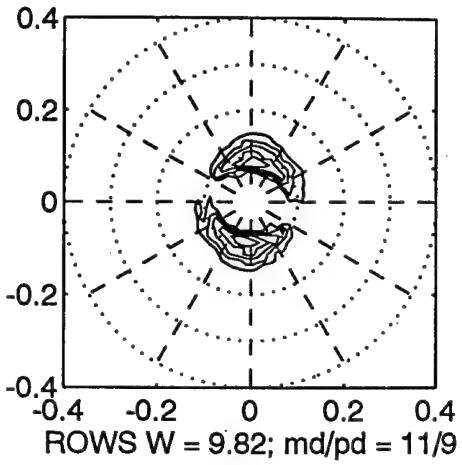

ROWS S0214b04
Direction, Deg.
200
100
0
-100
f_pk
d_phi_iso
phi_pk
10-1
Frequency, Hz

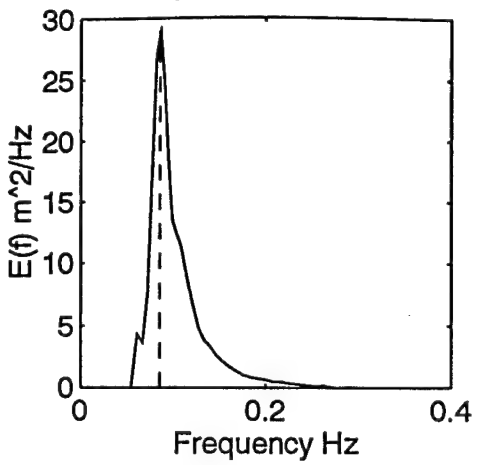

ROWS S0214b05
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

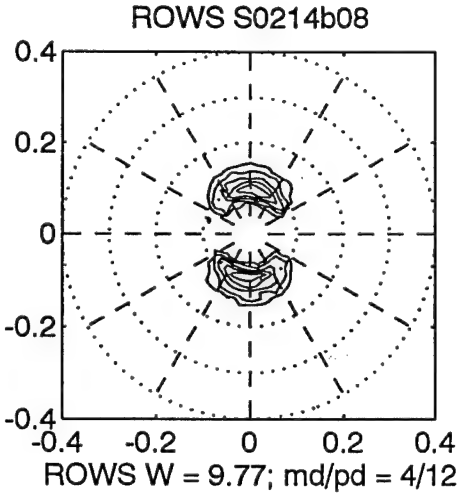

ROWS S0214b05
Direction, Deg.
200
100
0
-100
f_pk
d_phi_iso
phi_pk
10-1
Frequency, Hz

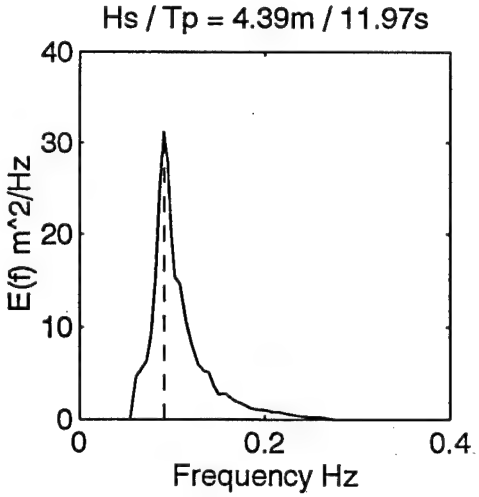

ROWS S0214b06
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

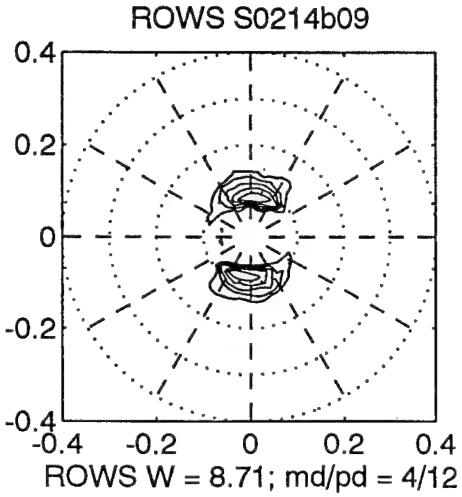

ROWS S0214b06
Direction, Deg.
200
100
0
-100
f_pk
d_phi_iso
phi_pk
10-1
Frequency, Hz

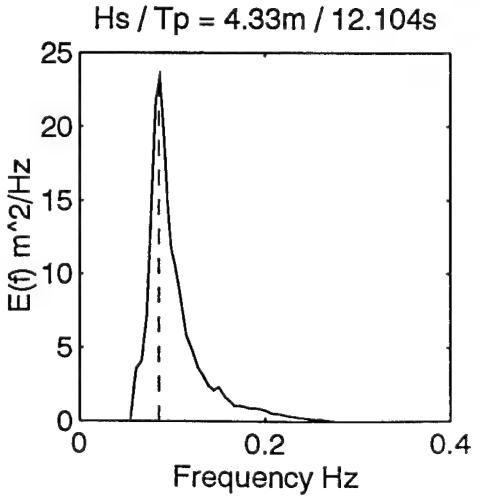

ROWS S0214b07
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 9.82; md/pd = 11/9

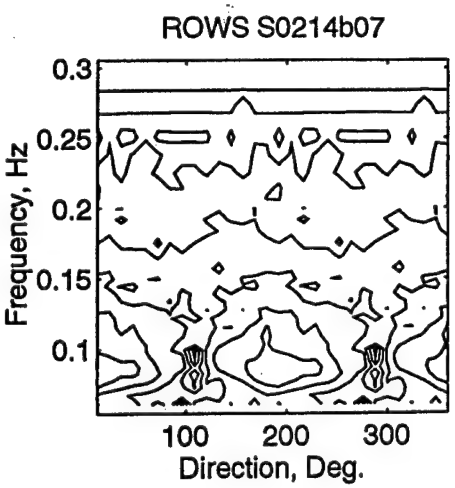

Hs / Tp = 4.37m / 12.104s
30
25
20
15
10
5
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz

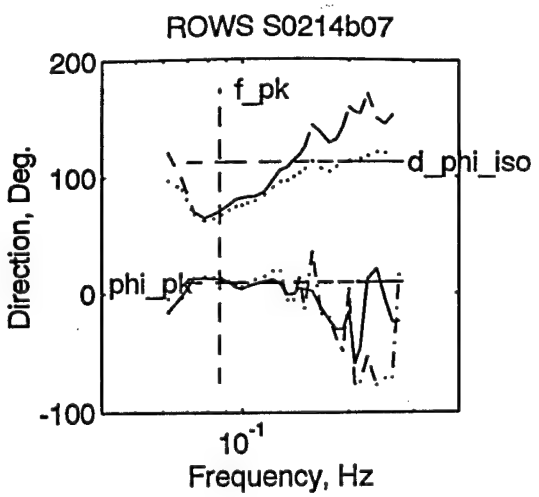

ROWS S0214b08
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 9.77; md/pd = 4/12

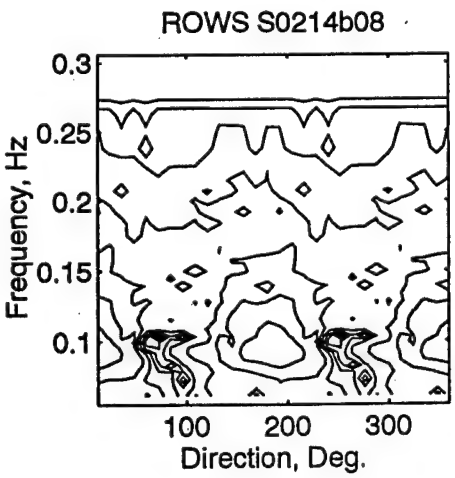

Hs / Tp = 4.39m / 11.97s
40
30
20
10
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz

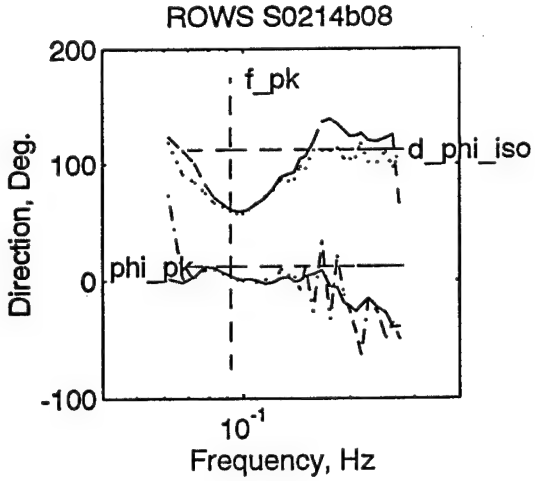

ROWS S0214b09
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 8.71; md/pd = 4/12

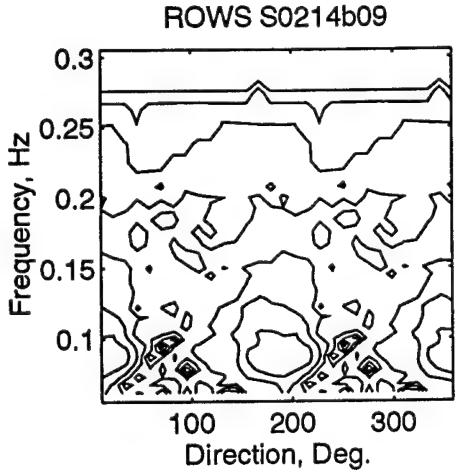

Hs / Tp = 4.33m / 12.104s
25
20
15
10
5
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz

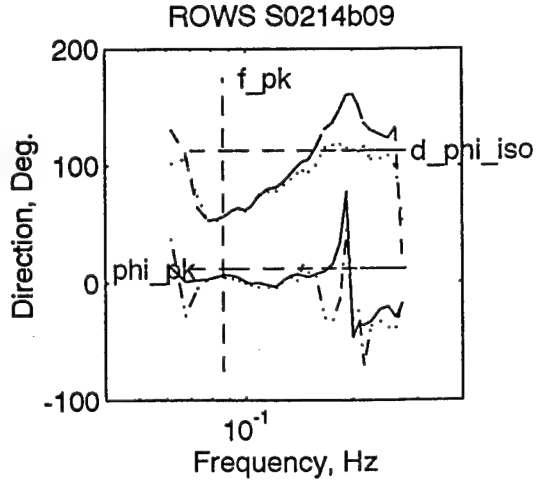

ROWS S0214b07
0.3
0.25
0.2
0.15
0.1
Frequency, Hz
100
200
300
Direction, Deg.

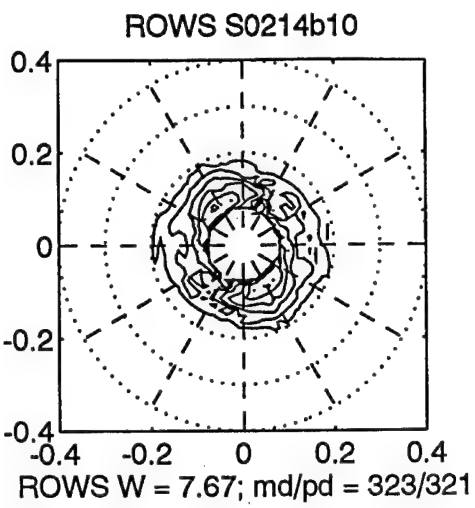

ROWS S0214b07
200
100
0
-100
Direction, Deg.
f_pk
d_phi_iso
phi_pk
10^{-1}
Frequency, Hz

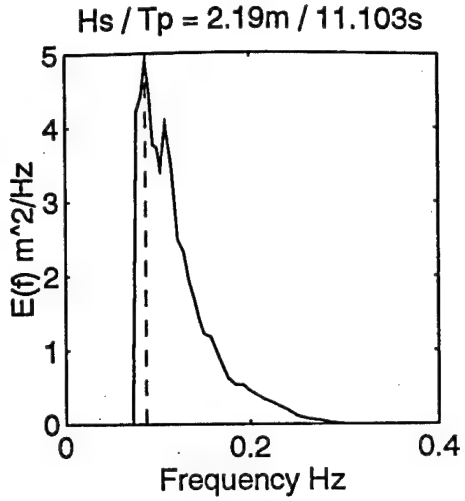

ROWS S0214b08
0.3
0.25
0.2
0.15
0.1
Frequency, Hz
100
200
300
Direction, Deg.

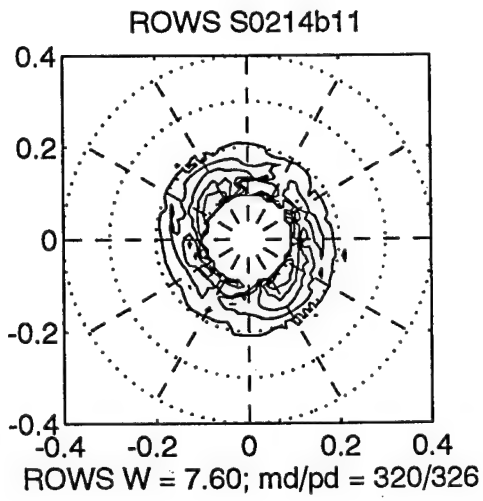

ROWS S0214b08
200
100
0
-100
Direction, Deg.
f_pk
d_phi_iso
phi_pk
10^{-1}
Frequency, Hz

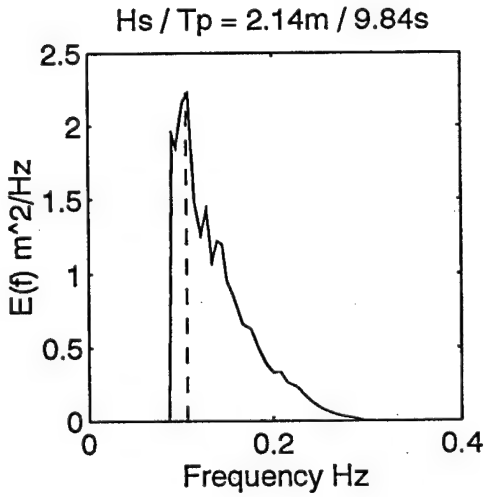

ROWS S0214b09
0.3
0.25
0.2
0.15
0.1
Frequency, Hz
100
200
300
Direction, Deg.

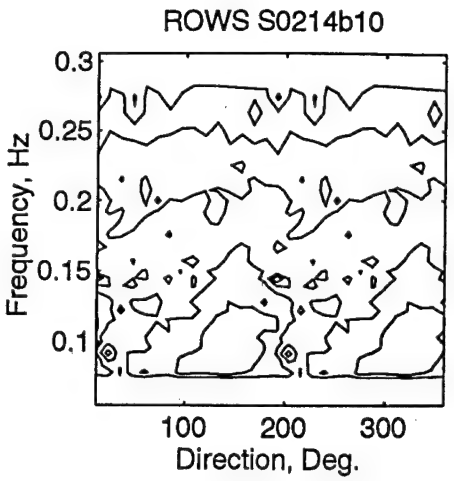

ROWS S0214b09
200
100
0
-100
Direction, Deg.
f_pk
d_phi_iso
phi_pk
10^{-1}
Frequency, Hz

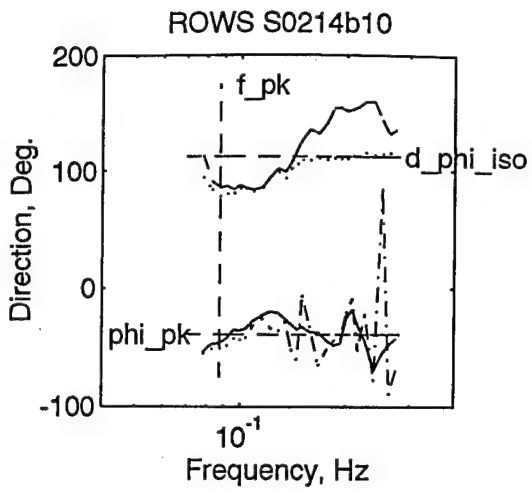

ROWS S0214b10
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 7.67; md/pd = 323/321

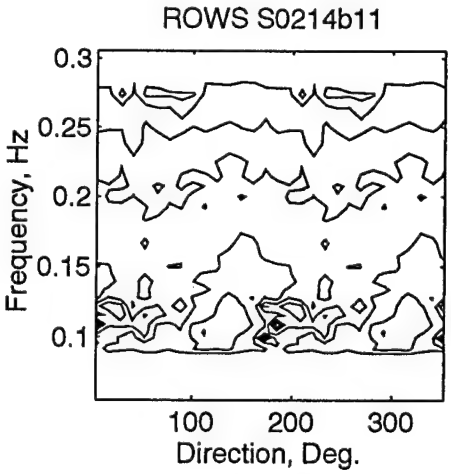

Hs / Tp = 2.19m / 11.103s
E(f) m^2/Hz
5
4
3
2
1
0
0 0.2 0.4
Frequency Hz

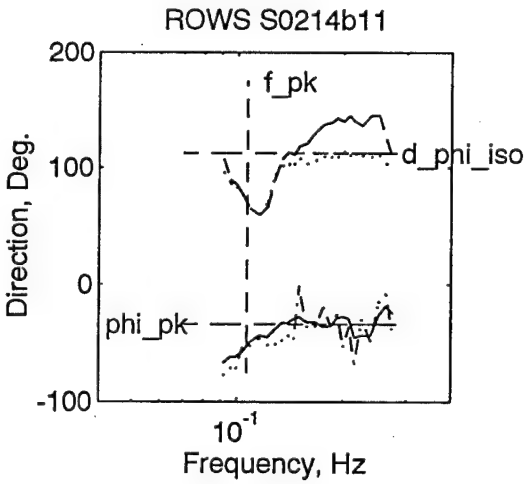

ROWS S0214b11
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 7.60; md/pd = 320/326


Hs / Tp = 2.14m / 9.84s
E(f) m^2/Hz
2.5
2
1.5
1
0.5
0
0 0.2 0.4
Frequency Hz

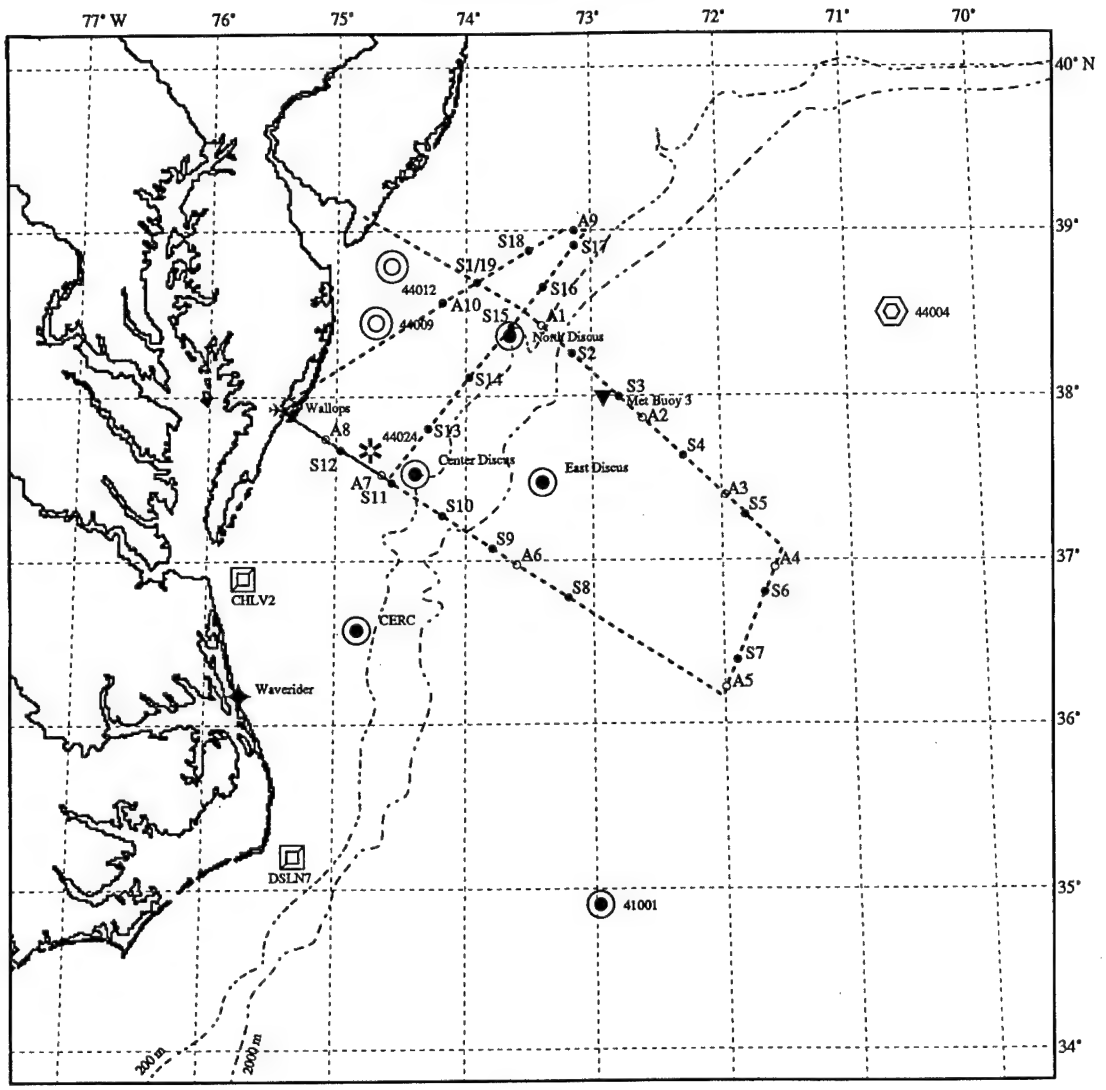

ROWS S0214b10
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.


ROWS S0214b10
Direction, Deg.
200
100
0
-100
f_pk
d_phi_iso
phi_pk
10^{-1}
Frequency, Hz


ROWS S0214b11
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.


ROWS S0214b11
Direction, Deg.
200
100
0
-100
f_pk
d_phi_iso
phi_pk
10^{-1}
Frequency, Hz

ROWS Flight
15 Feb 1991



Symbols

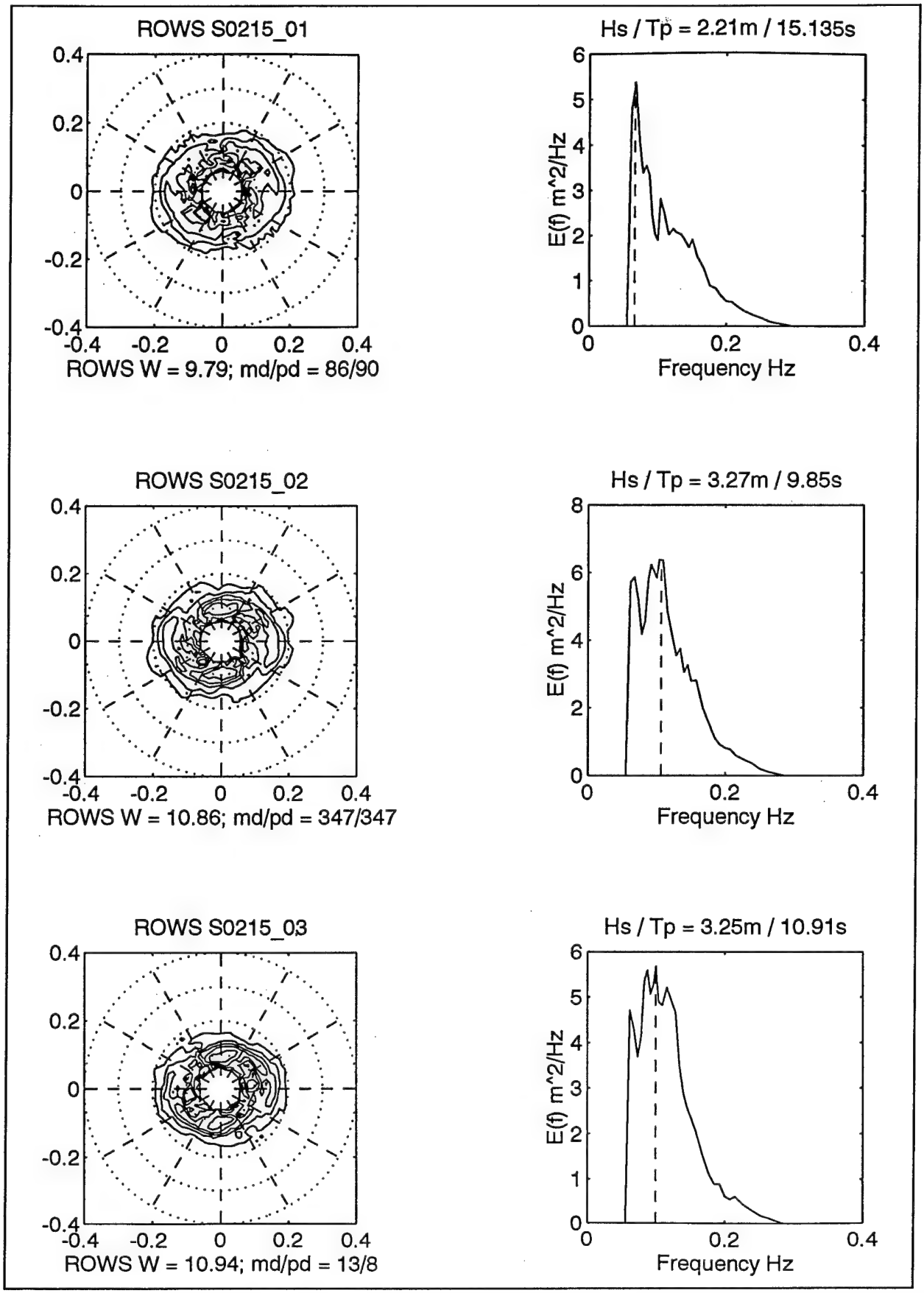
- Coastal Buoy
- 3m Discus Buoy
- 12m Discus Buoy
- 6m NORMAD Buoy
- 1m Met Buoy
- C-Man Station

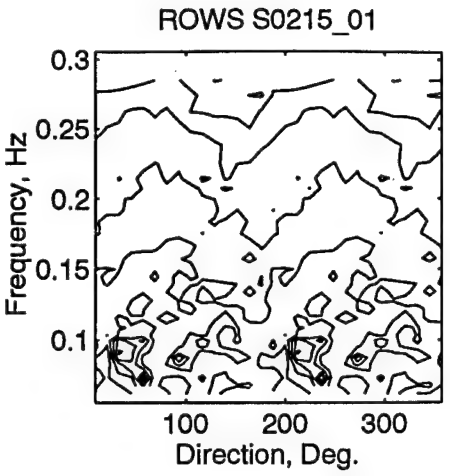
Lambert Conformal Projection
Aug93

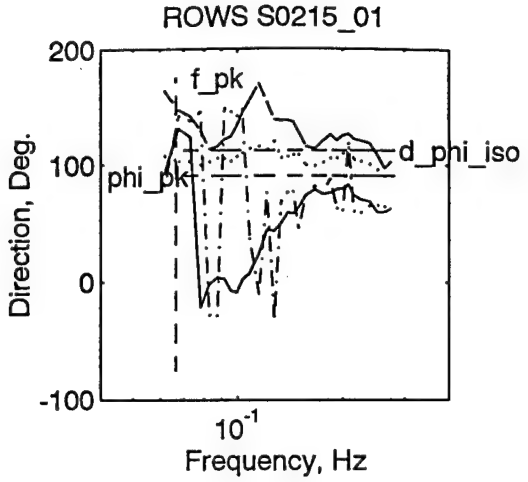
ROWS SWADE FLIGHT NAVIGATION AND FILE DATA
FEB 15, 1991

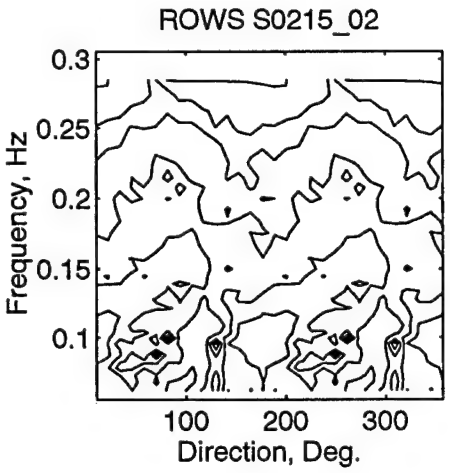
TAPE1/1 FILE	POS FIX	ROWS MODE	BUOY/ WP	EST HH MM SS	LAT	LON	ALT	SPD M/S	HDG TRU	PC-TIC START	REC # START	0 DEG DELTA	LEN MB
	1	1	SEI/3	15 27 00	39.09	-74.80	7625						
	1	0	4	15 31 03									
S01	0	1		15 34 23	38.69	-73.91	7625	182	138	153300	14901		12
	1	0	5′	15 38 08	38.53	-73.56	7625						
A01	0	2		15 40 05	38.43	-73.40	7625	172		153939	47901		2
S02	1	1		15 42 24	38.26	-73.16	7625	172	151	154107	53201		12
S03	0	1		15 47 10	38.00	-72.79	7625	167	152	154548	81301		12
A02	0	2		15 49 40	37.87	-72.61	7625			154907	98401		2
S04	0	1		15 53 24	37.64	-72.30	7625	161	154	155201	112401		12
A03	0	2		15 57 25	37.40	-71.97	7625			155650	138701		2
	1	0		15 59 23	37.30	-71.83	7625	155	156				
S05	0	1		15 59 38	37.28	-71.82	7625	155	156	155812	144501		12
	1	0	6′	16 02 52	37.08	-71.54	7625						
A04	0	2		16 06 40	36.96	-71.60	7625	104	212	160604	171701		2
	1	0		16 09 02	36.82	-71.67	7625	104	212				
S06	0	1		16 09 18	36.81	-71.68	7625	104	212	160715	175201		18
S07	1	1		16 17 16	36.39	-71.90	7625	108	209	161500	221401		18
A05	0	2		16 20 10	36.22	-71.99	7625	108	209	161927	244901		2
	1	0	7	16 21 05	36.16	-72.01	7625						
TAPE2/2													
S08	0	1		16 33 34	36.78	-73.20	7625	169	285	163341	6101		18
A06	0	2		16 38 03	36.98	-73.60	7625	169		163855	30801		2
S09	0	1		16 40 13	37.08	-73.79	7625	169	288	164013	35401		12
S10	0	1		16 44 16	37.28	-74.18	7625	169	288	164416	59701		12
S11	0	1		16 48 20	37.48	-74.57	7625	169	288	164815	83601		12
	1	0	8	16 48 40	37.50	-74.60	7625						
A07	0	2		16 50 00	37.53	-74.65	7625	174	285	164018	96201		2
	1	0		16 52 23	37.68	-74.97	7625						
S12	0	1		16 52 38	37.68	-74.97	7625	174	285	165235	104301		12
	1	0	WFF		37.94	-75.47	7625						
A08	1	2		17 00 34	37.75	-75.09	7625	186	150	170113	138101		2
	1	0	8	17 05 08	37.50	-74.60	7625						
S13	0	1		17 09 32	37.81	-74.29	7625	226	042	170921	180501		12
S14	1	1		17 13 56	38.12	-73.97	7625	226	042	171345	206901		12
S15	1	1	DIS-N	17 16 15	38.42	-73.64	7625	226	042	171604	214801		12
S16	0	1		17 19 08	38.66	-73.39	7625	227	042	171851	231401		12
S17	1	1	14	17 22 01	38.91	-73.14	7625	229	041	172140	248401		12
	1	0	TEMP		39.00	-73.03	7625						
A09	0	2		17 26 00	39.00	-73.14	7625						
	1	0	TEMP		39.00	-73.23	7625						
	1	0		17 27 50	38.95	-73.34	7625	149	227				
S18	0	1		17 29 20	38.88	-73.50	7625	149	227	172820	272201		18
S19	0	1		17 33 38	38.69	-73.91	7625	130	227	173244	297701		18
A10	0	2		17 36 03	38.57	-74.18	7625	121	227	173630	317001		2
	1	0		17 36 15	38.55	-74.20	7625						
	1	0	WFF	17 53 00	37.94	-75.47	0						

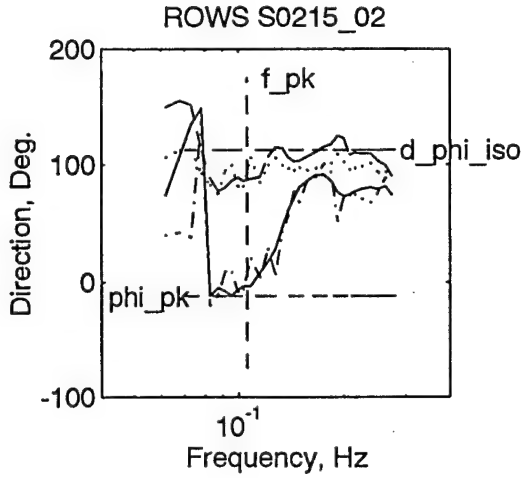
NOTES: (1) 138 DEG HEADING ON OUTBOUND LEG SOMEWHAT UNCERTAIN--CHECK S01 SPECTRUM WITH CROSSTRACK OVERLAY SPECTRUM S19. (2) INBOUND SOUTHERN LEG HEADING ESTIMATED FROM TRACK = 304 DEG MINUS DRIFT ANGLE.

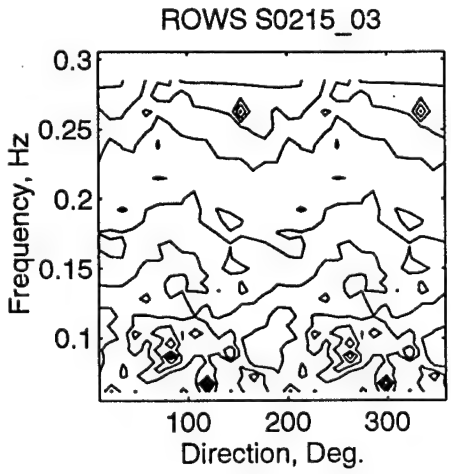

ROWS S0215_01
Hs / Tp = 2.21m / 15.135s
ROWS W = 9.79; md/pd = 86/90
E(f) m^2/Hz
Frequency Hz
ROWS S0215_02
Hs / Tp = 3.27m / 9.85s
ROWS W = 10.86; md/pd = 347/347
E(f) m^2/Hz
Frequency Hz
ROWS S0215_03
Hs / Tp = 3.25m / 10.91s
ROWS W = 10.94; md/pd = 13/8
E(f) m^2/Hz
Frequency Hz

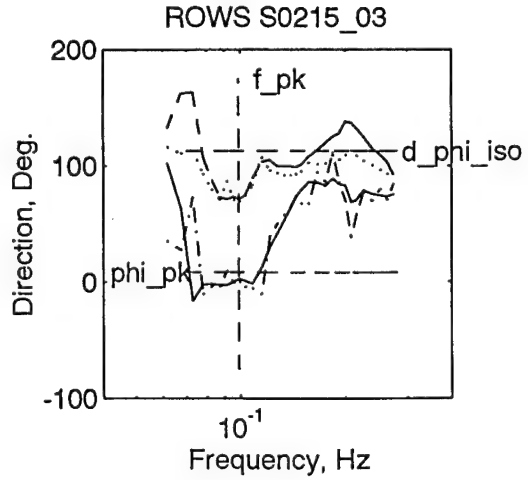

ROWS S0215_01
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

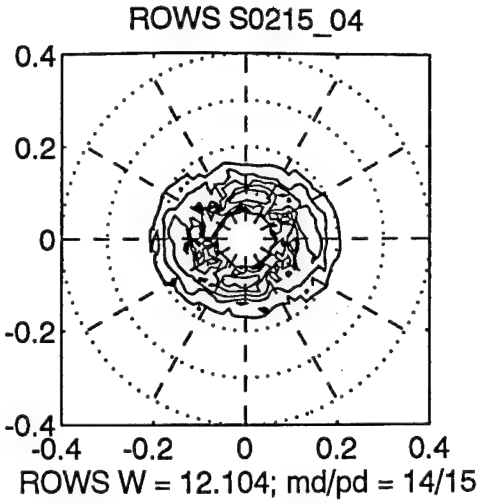

ROWS S0215_01
Direction, Deg.
200
100
0
-100
f_pk
phi_pk
d_phi_iso
10^{-1}
Frequency, Hz

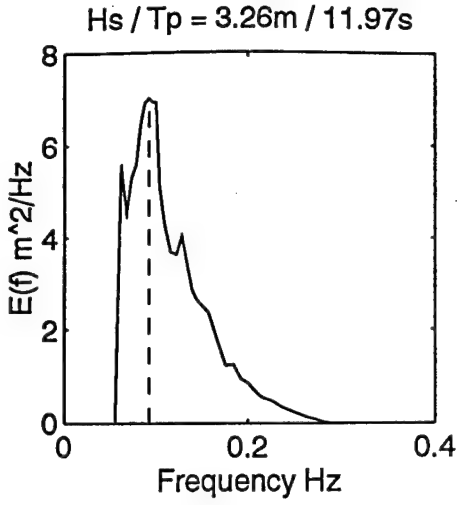

ROWS S0215_02
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

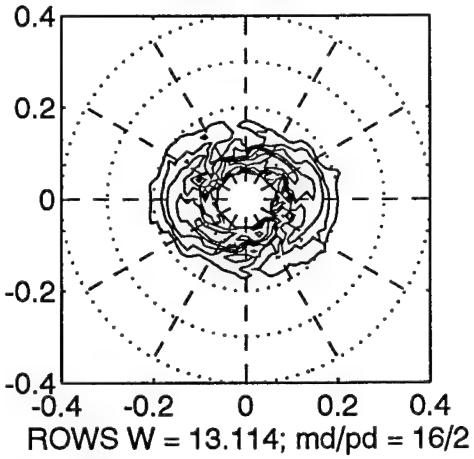

ROWS S0215_02
Direction, Deg.
200
100
0
-100
f_pk
d_phi_iso
phi_pk
10^{-1}
Frequency, Hz

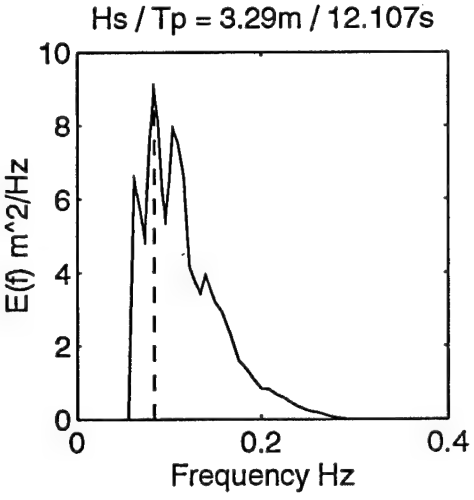

ROWS S0215_03
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

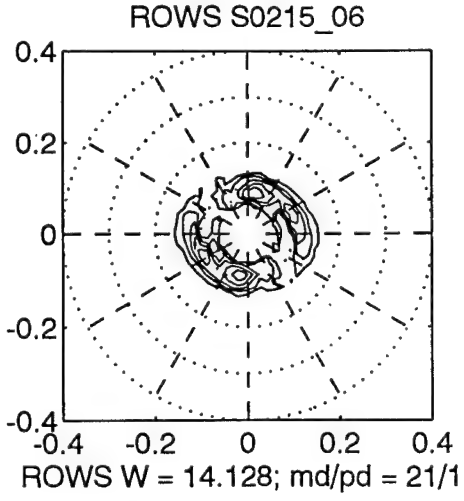

ROWS S0215_03
Direction, Deg.
200
100
0
-100
f_pk
d_phi_iso
phi_pk
10^{-1}
Frequency, Hz

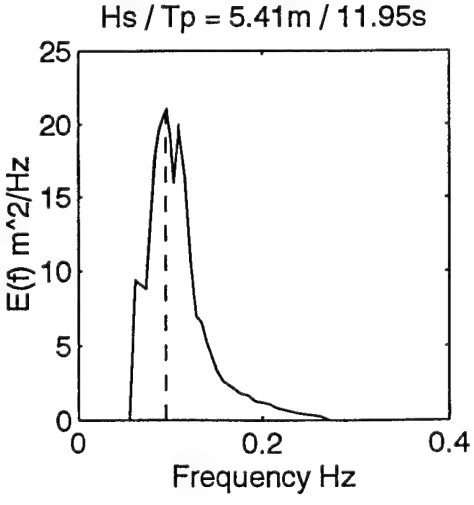

ROWS S0215_04
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 12.104; md/pd = 14/15

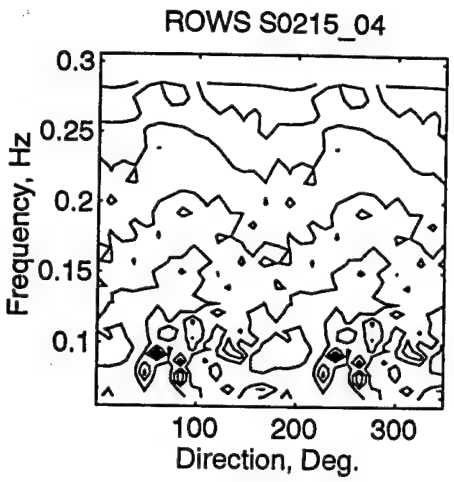

Hs / Tp = 3.26m / 11.97s
E(f) m^2/Hz
0 2 4 6 8
0 0.2 0.4
Frequency Hz

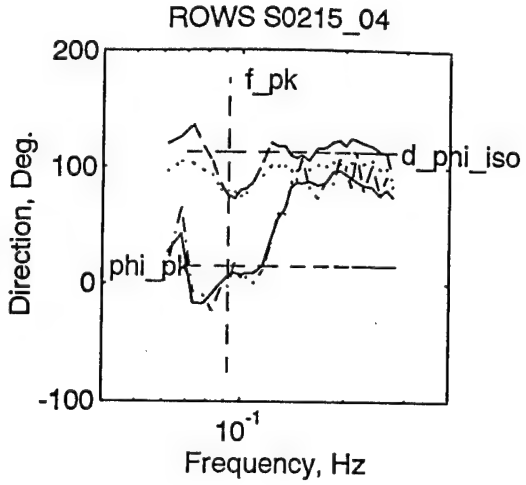

ROWS S0215_05
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 13.114; md/pd = 16/2

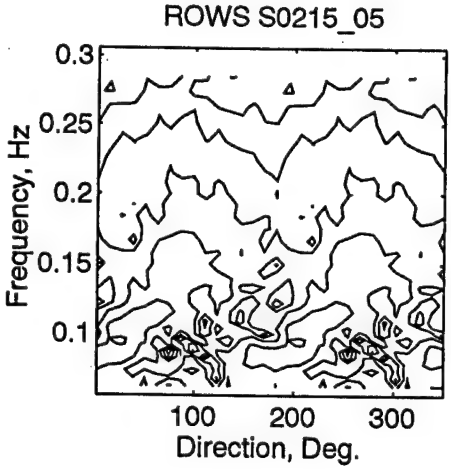

Hs / Tp = 3.29m / 12.107s
E(f) m^2/Hz
0 2 4 6 8 10
0 0.2 0.4
Frequency Hz

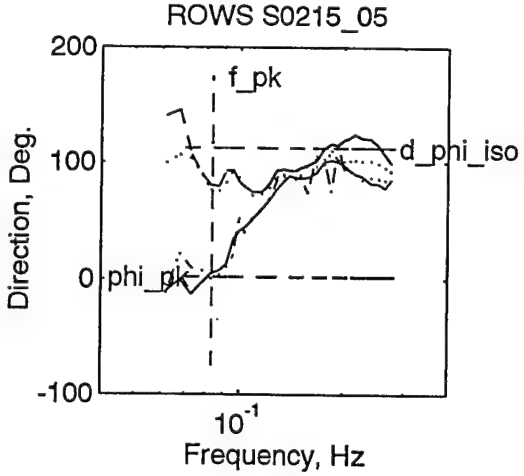

ROWS S0215_06
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 14.128; md/pd = 21/11

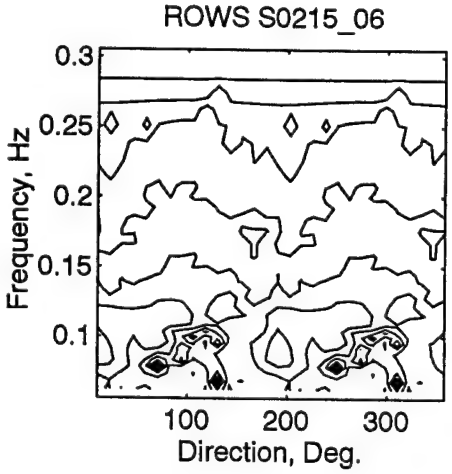

Hs / Tp = 5.41m / 11.95s
E(f) m^2/Hz
0 5 10 15 20 25
0 0.2 0.4
Frequency Hz

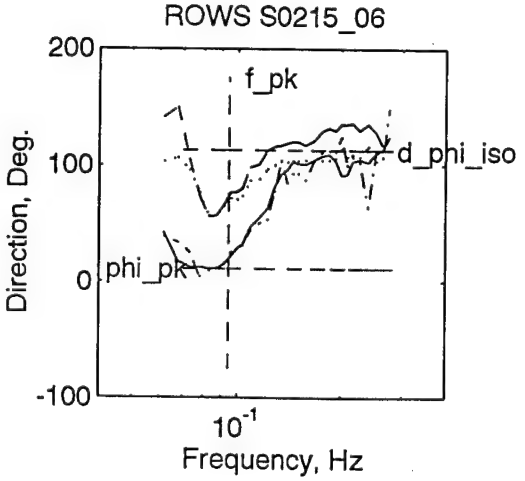

ROWS S0215_04
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

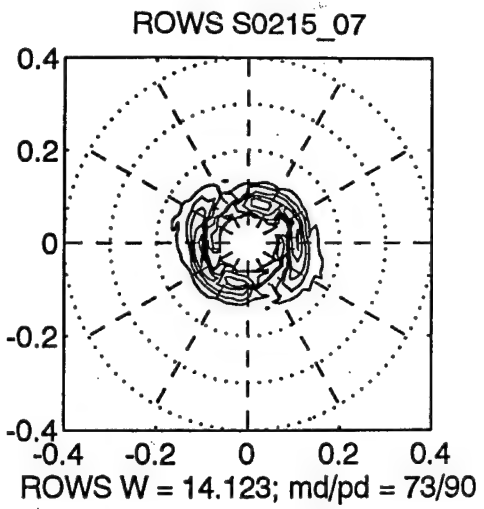

ROWS S0215_04
Direction, Deg.
200
100
0
-100
f_pk
d_phi_iso
phi_pk
10^{-1}
Frequency, Hz

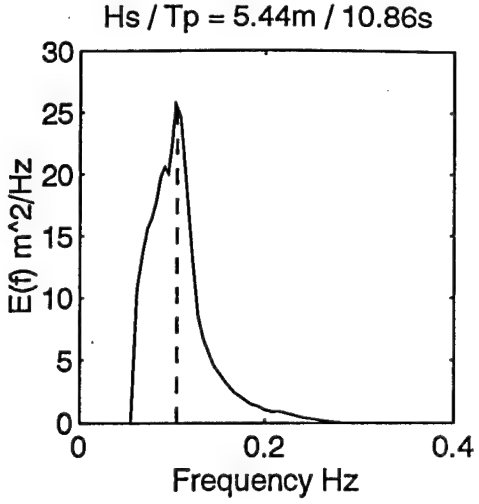

ROWS S0215_05
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

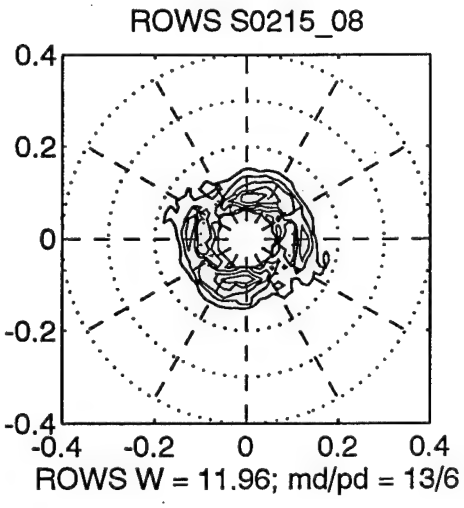

ROWS S0215_05
Direction, Deg.
200
100
0
-100
f_pk
d_phi_iso
phi_pk
10^{-1}
Frequency, Hz

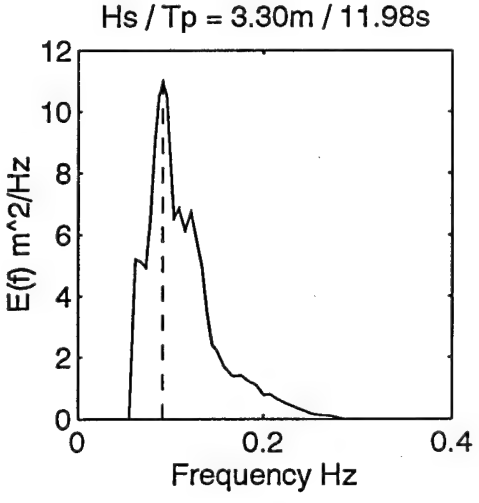

ROWS S0215_06
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

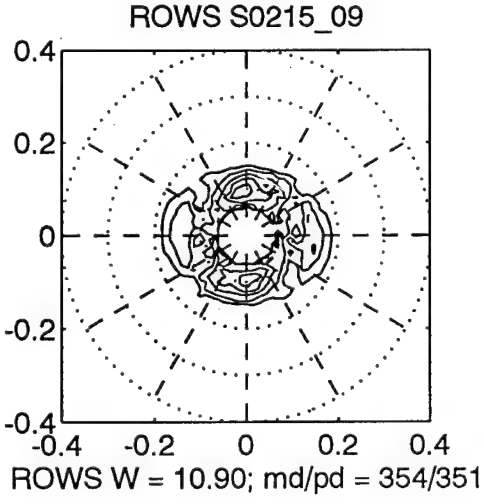

ROWS S0215_06
Direction, Deg.
200
100
0
-100
f_pk
d_phi_iso
phi_pk
10^{-1}
Frequency, Hz

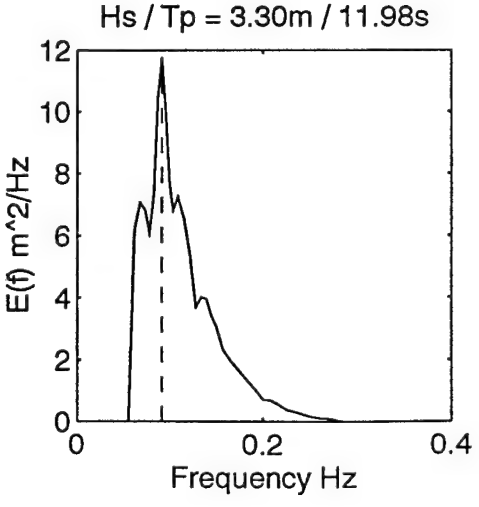

ROWS S0215_07
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 14.123; md/pd = 73/90

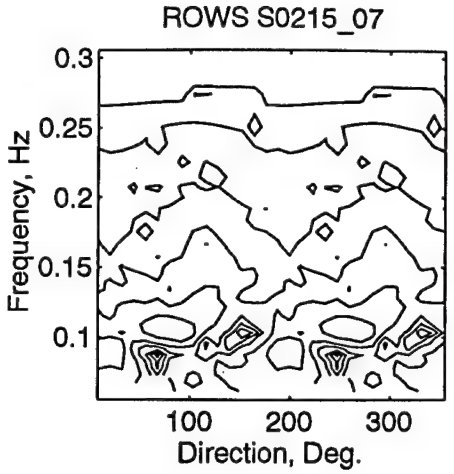

Hs / Tp = 5.44m / 10.86s
30
25
20
15
10
5
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz

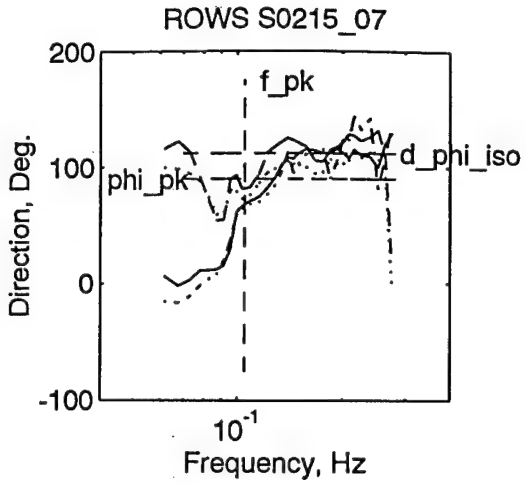

ROWS S0215_08
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 11.96; md/pd = 13/6

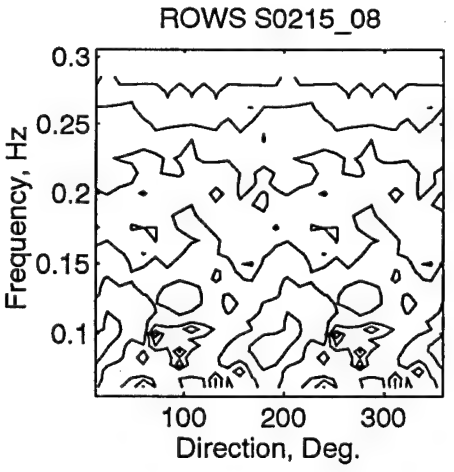

Hs / Tp = 3.30m / 11.98s
12
10
8
6
4
2
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz

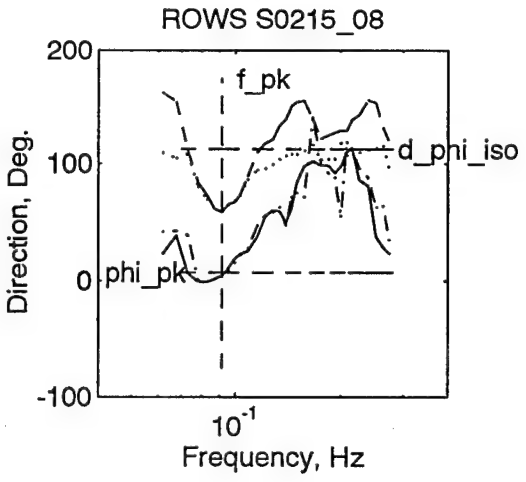

ROWS S0215_09
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 10.90; md/pd = 354/351

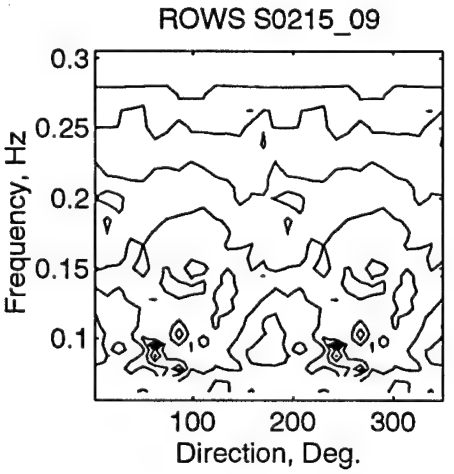

Hs / Tp = 3.30m / 11.98s
12
10
8
6
4
2
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz

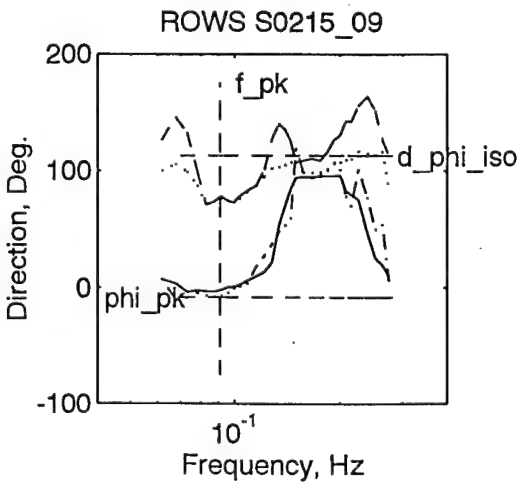

ROWS S0215_07
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

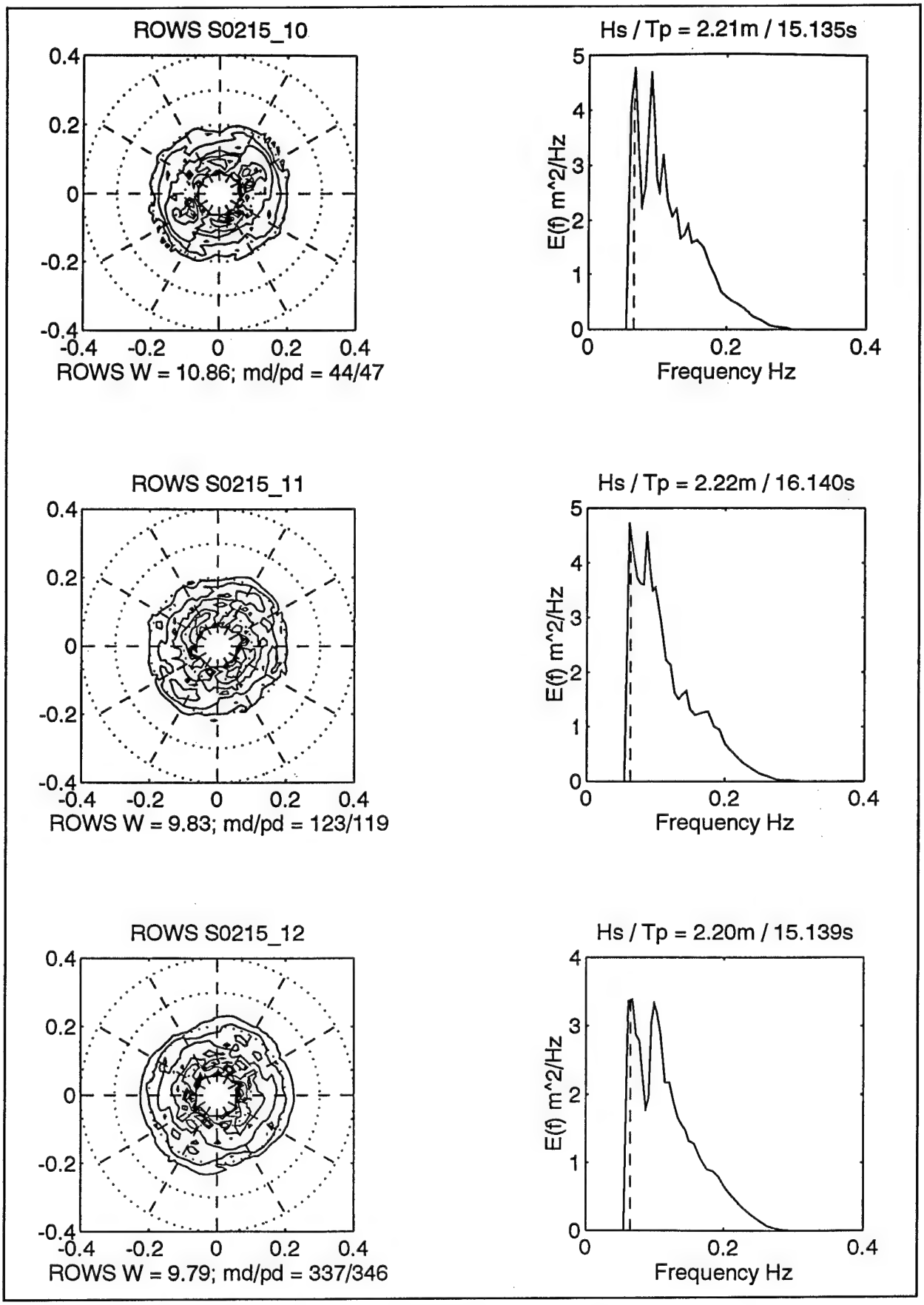

ROWS S0215_07
Direction, Deg.
200
100
0
-100
f_pk
phi_pk
d_phi_iso
10^{-1}
Frequency, Hz

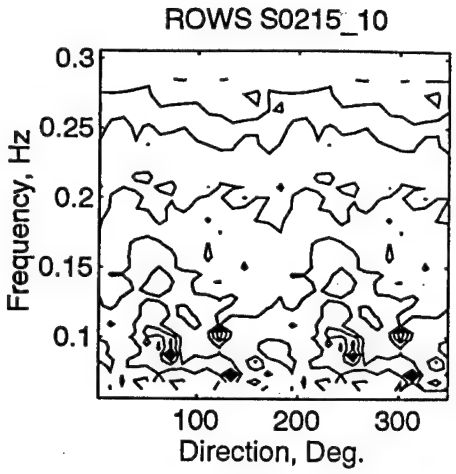

ROWS S0215_08
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

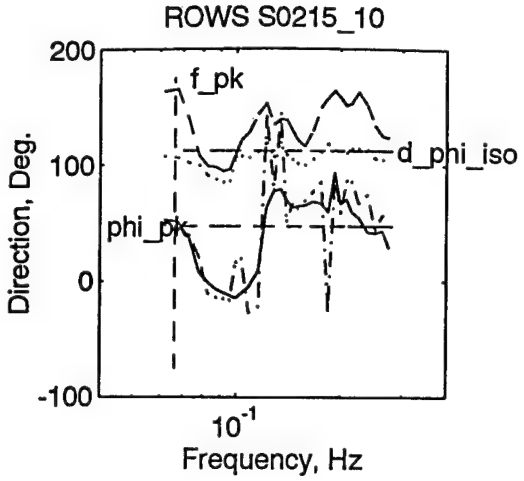

ROWS S0215_08
Direction, Deg.
200
100
0
-100
f_pk
d_phi_iso
phi_pk
10^{-1}
Frequency, Hz

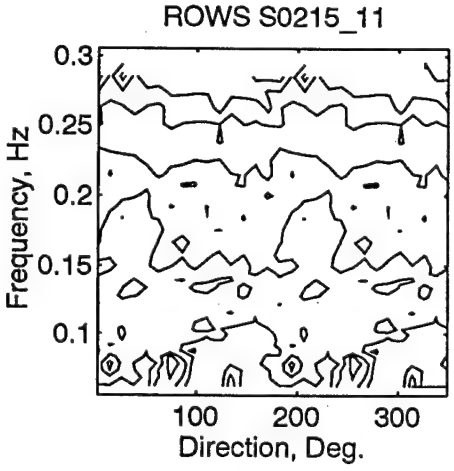

ROWS S0215_09
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

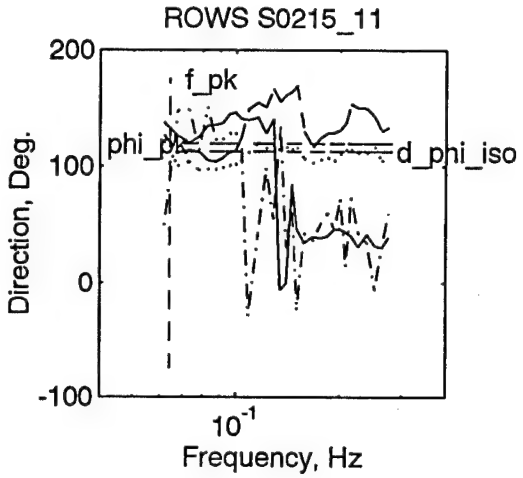

ROWS S0215_09
Direction, Deg.
200
100
0
-100
f_pk
d_phi_iso
phi_pk
10^{-1}
Frequency, Hz

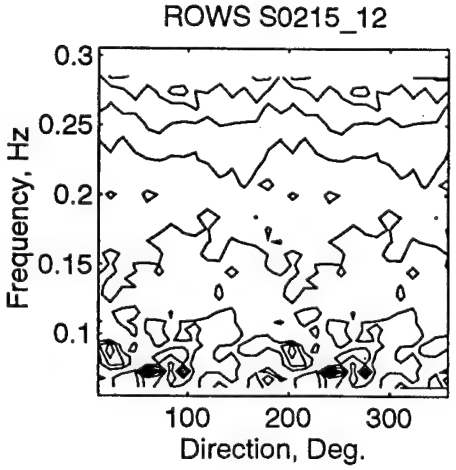

ROWS S0215_10
Hs / Tp = 2.21m / 15.135s
ROWS W = 10.86; md/pd = 44/47
E(f) m^2/Hz
Frequency Hz
ROWS S0215_11
Hs / Tp = 2.22m / 16.140s
ROWS W = 9.83; md/pd = 123/119
E(f) m^2/Hz
Frequency Hz
ROWS S0215_12
Hs / Tp = 2.20m / 15.139s
ROWS W = 9.79; md/pd = 337/346
E(f) m^2/Hz
Frequency Hz

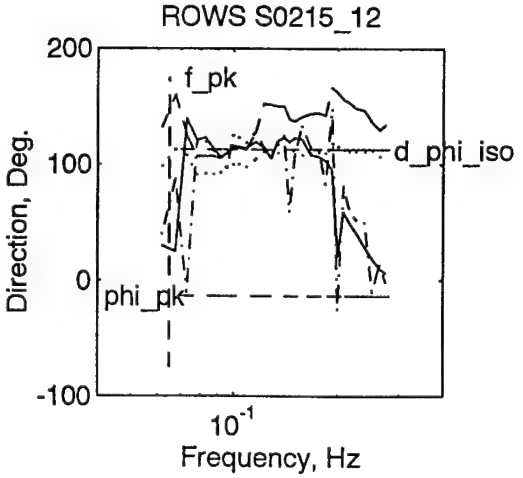

ROWS S0215_10
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

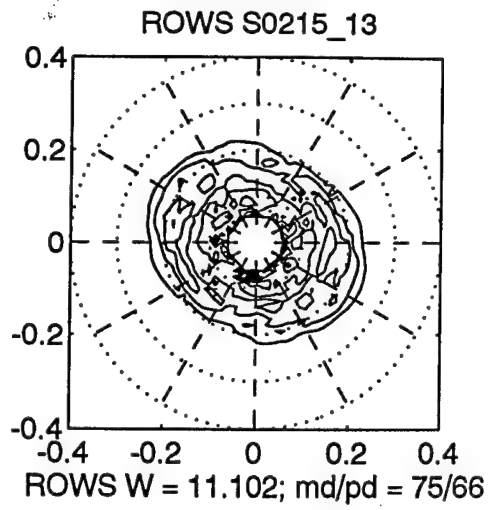

ROWS S0215_10
Direction, Deg.
200
100
0
-100
f_pk
d_phi_iso
phi_pk
10^{-1}
Frequency, Hz

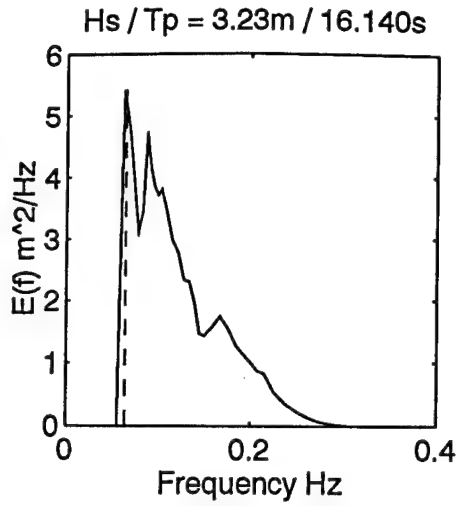

ROWS S0215_11
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

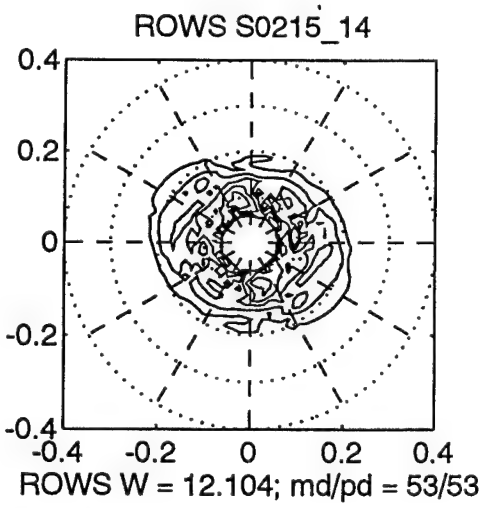

ROWS S0215_11
Direction, Deg.
200
100
0
-100
f_pk
phi_pk
d_phi_iso
10^{-1}
Frequency, Hz

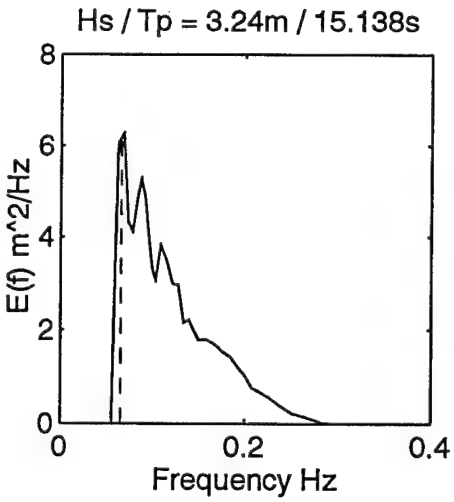

ROWS S0215_12
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

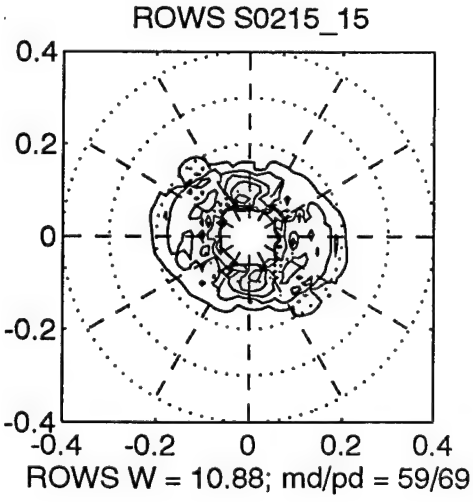

ROWS S0215_12
Direction, Deg.
200
100
0
-100
f_pk
d_phi_iso
phi_pk
10^{-1}
Frequency, Hz

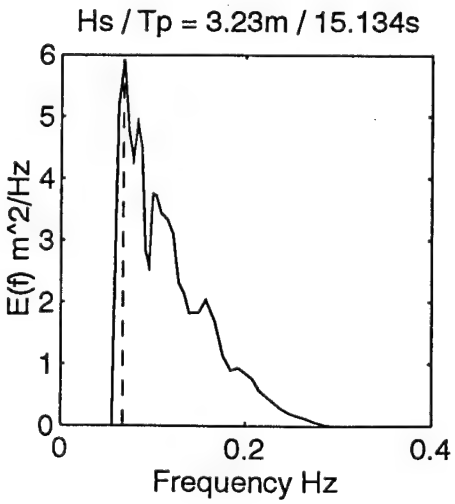

ROWS S0215_13
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 11.102; md/pd = 75/66

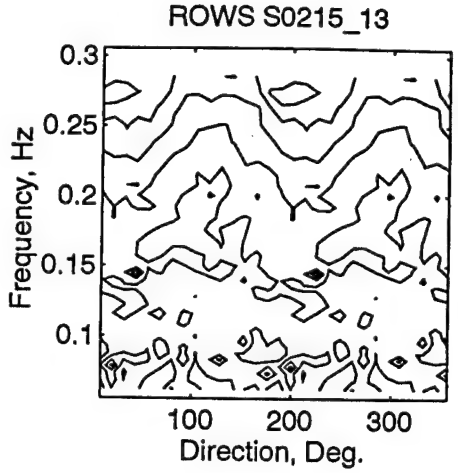

Hs / Tp = 3.23m / 16.140s
E(f) m^2/Hz
0 1 2 3 4 5 6
0 0.2 0.4
Frequency Hz

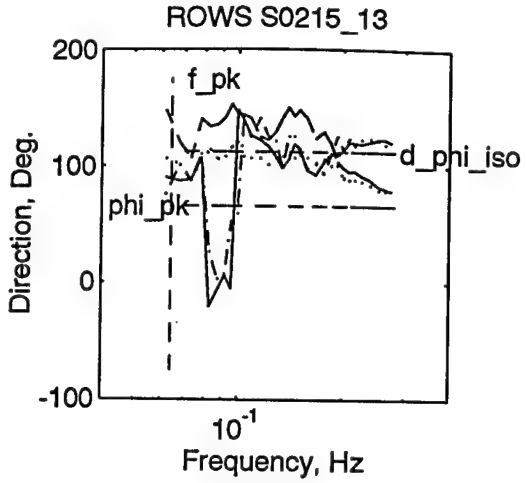

ROWS S0215_14
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 12.104; md/pd = 53/53

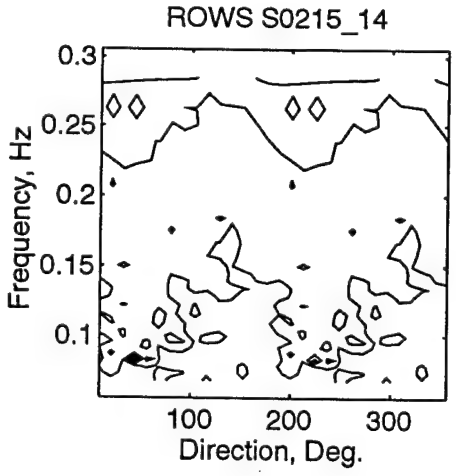

Hs / Tp = 3.24m / 15.138s
E(f) m^2/Hz
0 2 4 6 8
0 0.2 0.4
Frequency Hz

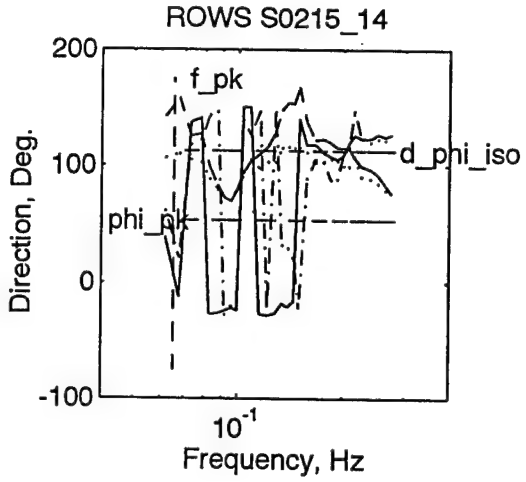

ROWS S0215_15
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 10.88; md/pd = 59/69

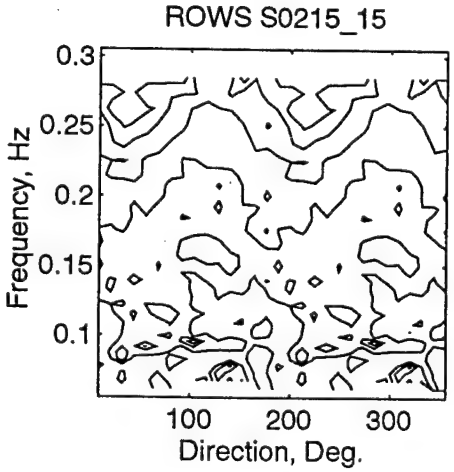

Hs / Tp = 3.23m / 15.134s
E(f) m^2/Hz
0 1 2 3 4 5 6
0 0.2 0.4
Frequency Hz

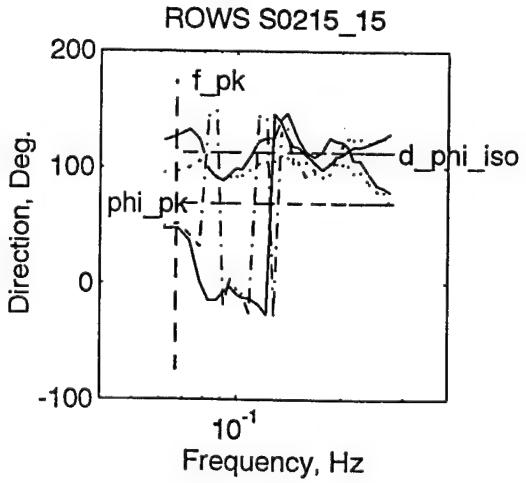

ROWS S0215_13
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

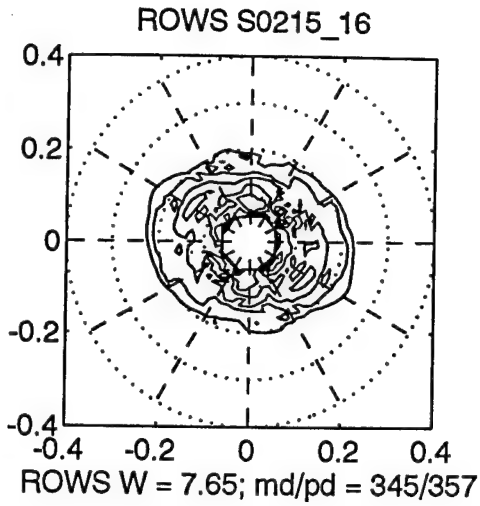

ROWS S0215_13
Direction, Deg.
200
100
0
-100
f_pk
d_phi_iso
phi_pk
10^{-1}
Frequency, Hz

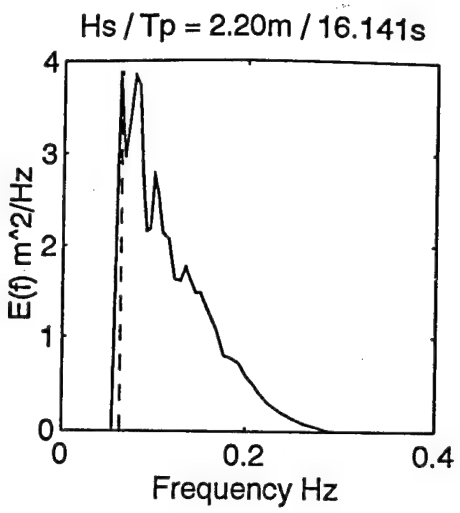

ROWS S0215_14
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

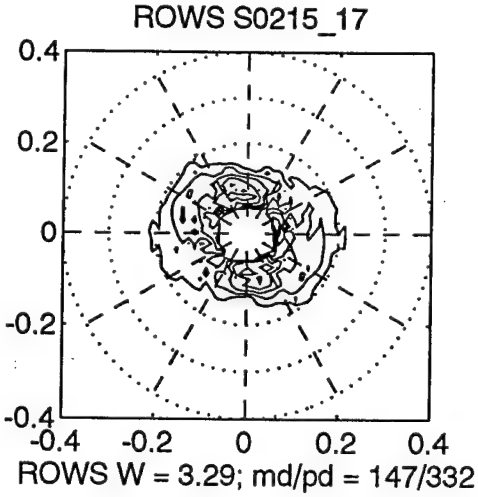

ROWS S0215_14
Direction, Deg.
200
100
0
-100
f_pk
d_phi_iso
phi_pk
10^{-1}
Frequency, Hz

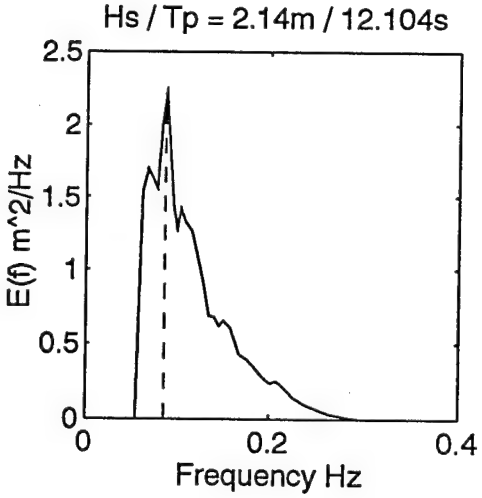

ROWS S0215_15
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

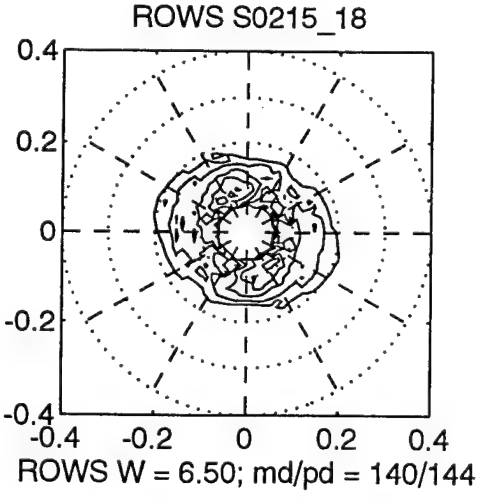

ROWS S0215_15
Direction, Deg.
200
100
0
-100
f_pk
d_phi_iso
phi_pk
10^{-1}
Frequency, Hz

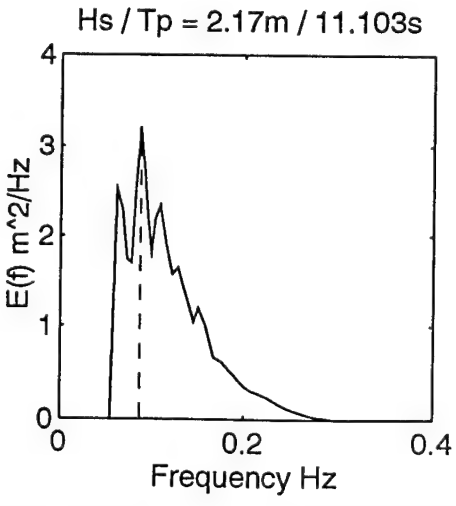

ROWS S0215_16
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 7.65; md/pd = 345/357

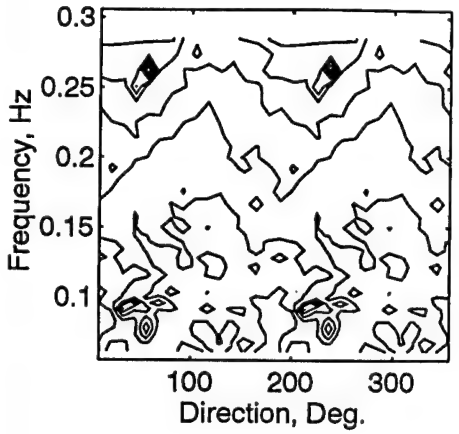

Hs / Tp = 2.20m / 16.141s
E(f) m^2/Hz
4
3
2
1
0
0 0.2 0.4
Frequency Hz

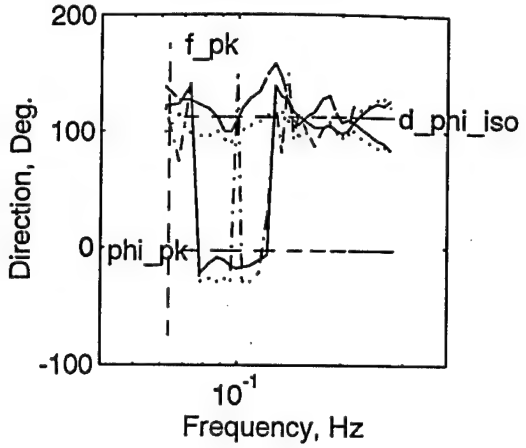

ROWS S0215_17
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 3.29; md/pd = 147/332

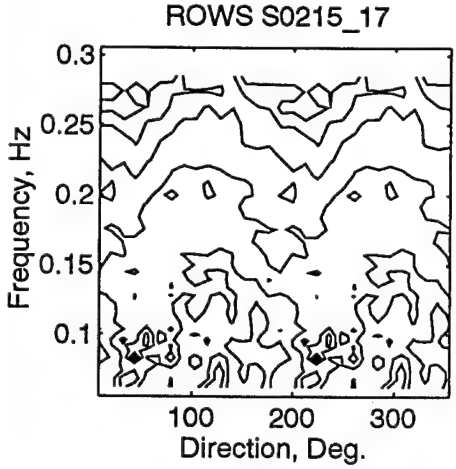

Hs / Tp = 2.14m / 12.104s
E(f) m^2/Hz
2.5
2
1.5
1
0.5
0
0 0.2 0.4
Frequency Hz

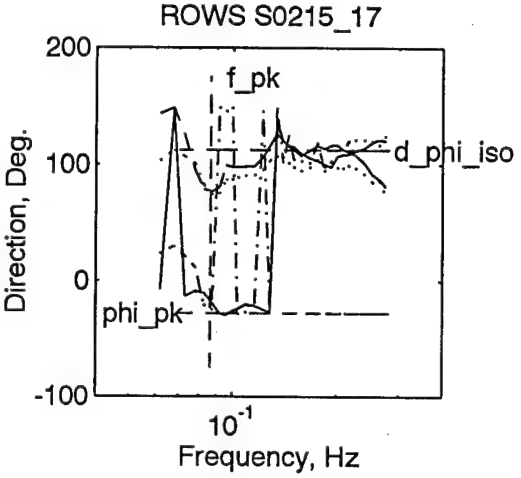

ROWS S0215_18
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 6.50; md/pd = 140/144

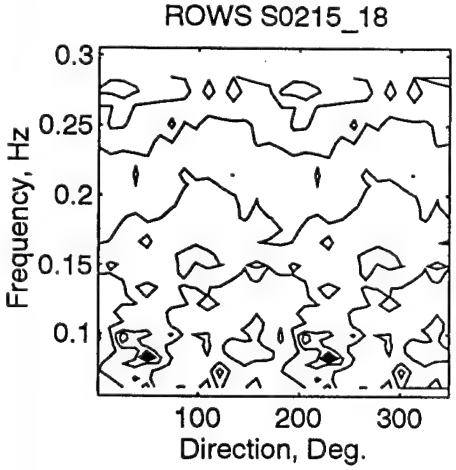

Hs / Tp = 2.17m / 11.103s
E(f) m^2/Hz
4
3
2
1
0
0 0.2 0.4
Frequency Hz

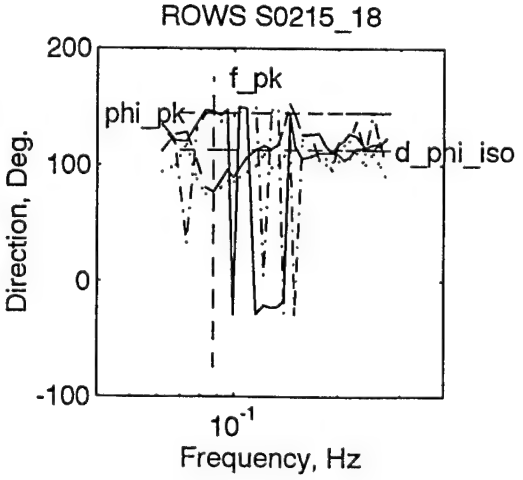

ROWS S0215_16
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

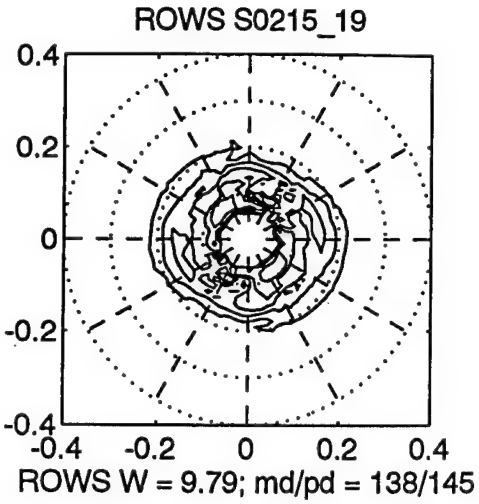

ROWS S0215_16
Direction, Deg.
200
100
0
-100
f_pk
d_phi_iso
phi_pk
10^{-1}
Frequency, Hz

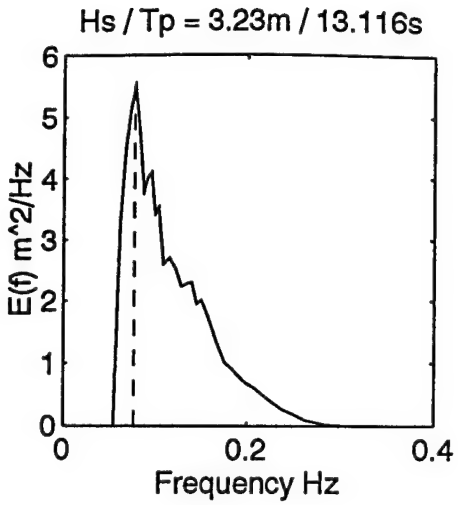

ROWS S0215_17
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

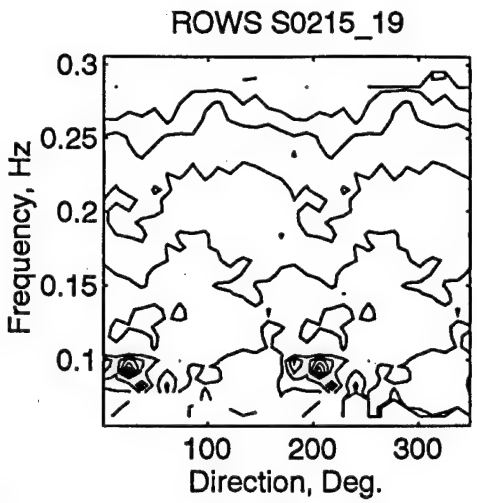

ROWS S0215_17
Direction, Deg.
200
100
0
-100
f_pk
d_phi_iso
phi_pk
10^{-1}
Frequency, Hz

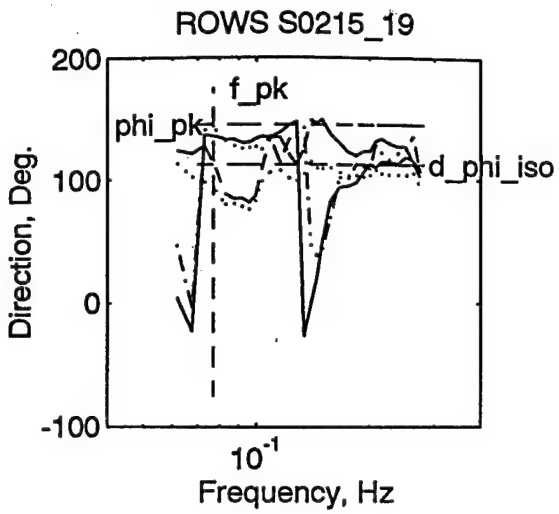

ROWS S0215_18
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

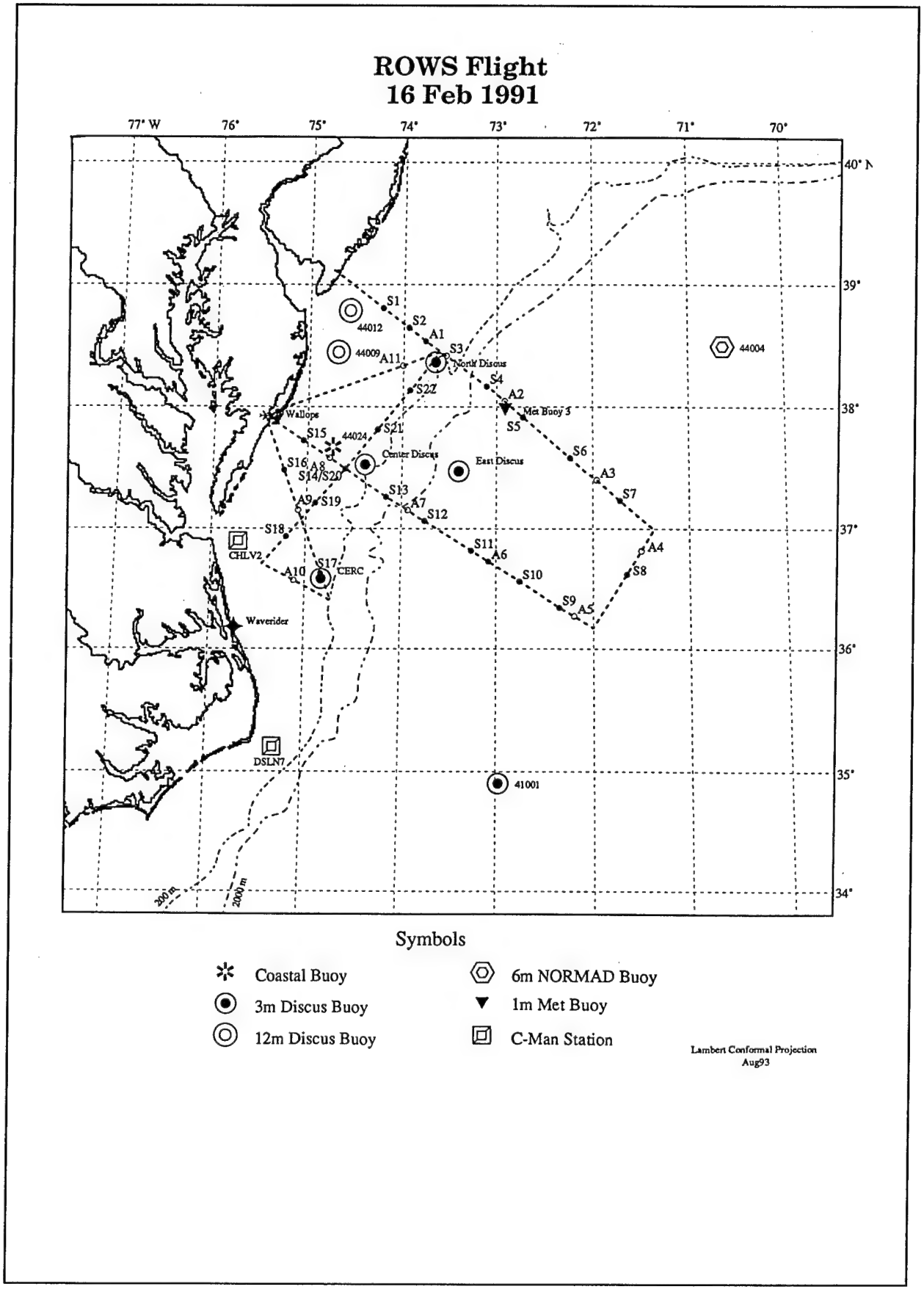

ROWS S0215_18
Direction, Deg.
200
100
0
-100
f_pk
phi_pk
d_phi_iso
10^{-1}
Frequency, Hz


ROWS S0215_19
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 9.79; md/pd = 138/145


Hs / Tp = 3.23m / 13.116s
E(f) m^2/Hz
6
5
4
3
2
1
0
0 0.2 0.4
Frequency Hz


ROWS S0215_19
0.3
0.25
0.2
0.15
0.1
Frequency, Hz
100
200
300
Direction, Deg.

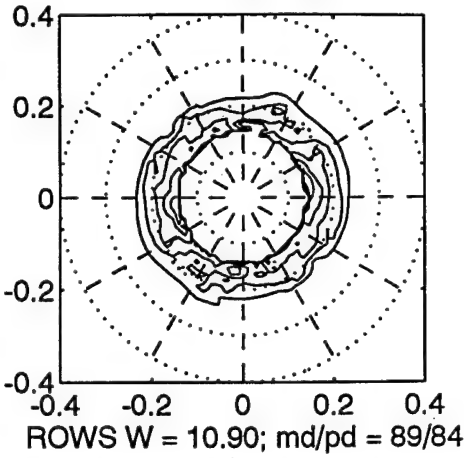

ROWS S0215_19
200
100
0
-100
Direction, Deg.
f_pk
phi_pk
d_phi_iso
10-1
Frequency, Hz

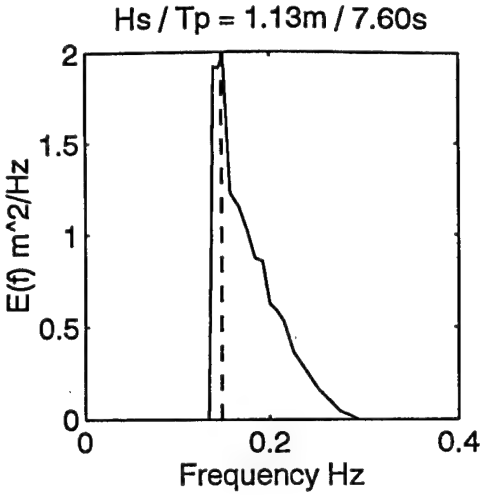

ROWS Flight
16 Feb 1991
77° W
76°
75°
74°
73°
72°
71°
70°
40° N
39°
38°
37°
36°
35°
34°
S1
S2
A1
S3
S4
A2
S5
S6
A3
S7
A4
S8
S9
A5
S10
A6
S11
S12
A7
S13
S14/S20
A8
S15
S16
A9
S17
A10
S18
S19
S21
S22
A11
44012
44009
44004
44024
41001
Wallops
North Discus
Met Buoy 3
Center Discus
East Discus
CERC
CHLV2
DSLN7
Waverider
200 m
2000 m
Symbols
Coastal Buoy
3m Discus Buoy
12m Discus Buoy
6m NORMAD Buoy
1m Met Buoy
C-Man Station
Lambert Conformal Projection
Aug93

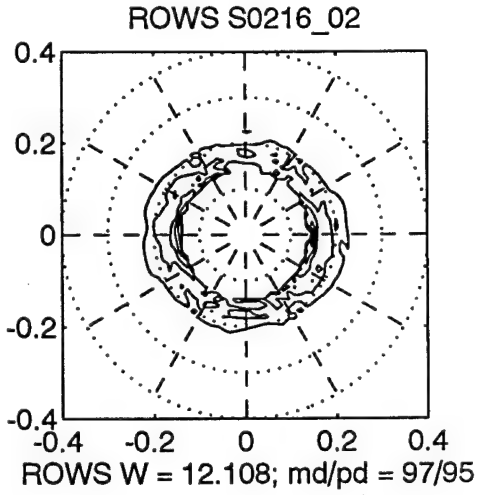
ROWS SWADE FLIGHT NAVIGATION AND FILE DATA
FEB 16, 1991

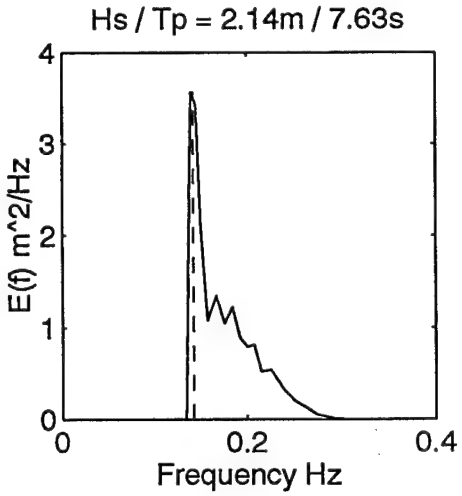
TAPE1/1 FILE	POS FIX	ROWS MODE	BUOY/ WP	EST HH MM SS	LAT DEG N	LON DEG E	ALT M	SPD M/S	HDG TRU	PC-TIC START	REC # START	0 DEG DELTA	LEN ME
	[1	0	SIE/3	09 27 28	39.12	-74.76	7625]						
	1	0	3′	09 27 28	39.17	-74.76	7625						
	[1	1		09 32 42	38.84	-74.21	7625	187	130]				
S01	1	1	′	09 32 42	38.81	-74.22	7625	187	130	093235	8401		12
S02	0	1		09 35 21	38.65	-73.94	7625	187	130	093513	24201		12
A01	0	2		09 37 13	38.54	-73.76	7625	187	130	093804	39801		2
S03	0	1	DIS-N	09 39 21	38.42	-73.54	7625	187	130	093909	45201		12
S04	0	1		09 43 40	38.17	-73.11	7625	187	130	094328	71101		12
	1	0		09 44 14	38.14	-73.05	7625	194	133				
A02	0	2		09 45 36	38.05	-72.92	7625	194	133	094616	86301		2
S05	0	1		09 47 38	37.92	-72.73	7625	196	133	094727	90701		12
S06	0	1		09 52 48	37.59	-72.23	7625	196	133	095236	121701		12
	1	0		09 54 23	37.48	-72.08	7625	196	133				
A03	0	2		09 55 15	37.41	-71.96	7625	196	133	095549	139801		2
S07	0	1		09 57 58	37.24	-71.72	7625	196	133	095742	149101		12
	1	0	6	10 01 17	37.00	-71.37	7625						
A04	0	2		10 02 30	36.82	-71.50	7625	175	218	100305	179801		2
S08	1	1		10 05 02	36.62	-71.65	7625	175	218	100418	185701		18
	1	0	7	10 10 15	36.17	-72.00	7625						
A05	0	2		10 12 30	36.27	-72.19	7625	173	299	101304	235701		2
S09	0	1		10 14 13	36.34	-72.34	7625	173	299	101358	239801		12
S10	0	1		10 18 27	36.56	-72.76	7625	173	299	101811	265201		12
	1	0		10 18 58	36.59	-72.81	7625	173	299				
A06	0	2		10 21 45	36.73	-73.08	7625	172	300	102215	289001		2
S11	0	1		10 23 40	36.82	-73.26	7625	171	301	102322	293301		12
S12	0	1		10 28 46	37.07	-73.75	7625	169	302	102830	324101		12
	1	0		10 29 28	37.10	-73.82	7625	169	302				
A07	0	2		10 30 30	37.16	-73.93	7625	170	302	103103	338201		2
S13	0	1		10 33 00	37.27	-74.16	7625	172	302	103246	347301		12
S14	1	1	8	10 37 10	37.50	-74.60	7625	174	301	103652	372000		12
A08	0	2		10 38 52	37.59	-74.77	7625	175	300	103925	386101		2
S15	0	1		10 41 38	37.73	-75.05	7625	176	300	104106	391401		12
	[1	0		10 44 32	37.92	-75.27	7625	178	300]				
	1	0	WFF	10 45 49	37.94	-75.47	7625						
S16	1	1		10 52 27	37.49	-75.25	7625	188	159	105205	455501		12
A09	0	2		10 55 52	37.16	-75.09	7625	188	159	105622	479201		2
S17	0	1		11 01 10	36.63	-74.84	7625	188	159	110013	540401		18
	1	0	CERC/9	11 01 40	36.59	-74.82	7625	188	159				
	1		TEMP	11 02 50	36.40	-74.73	7625						
A10	1	2		11 07 37	36.57	-75.12	7625	177	298	110806	539201		6
	1	0	TEMP	11 08 50	36.71	-75.46	7625						
S18	1	1		11 12 47	36.94	-75.21	7625	203	041	111220	561101		12
S19	0	1		11 16 07	37.22	-74.91	7625	203	041	111540	581101		12
S20	1	1	8	11 19 28	37.50	-74.60	7625	203	040	112001	607201		12
S21	0	1		11 23 21	37.82	-74.26	7625	202	039	112354	630501		12
S22	0	1		11 27 15	38.14	-73.92	7625	202	038	112747	653801		12
	1	0		11 27 45	38.18	-73.87	7625	202	038				
	1	0	11′		38.45	-73.61	7625						

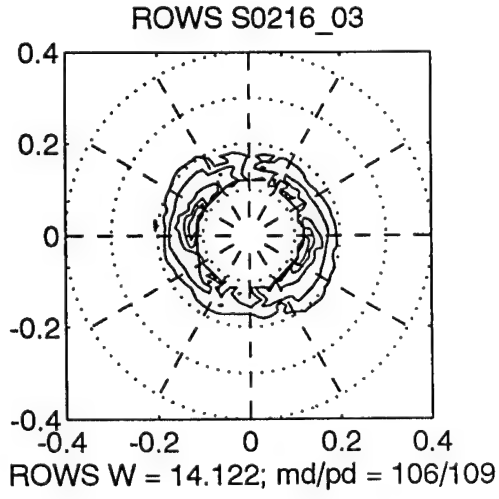
```
         0    2          11 34 30 38.34 -74.00 7625          113500 692001          2
         1    0     WFF  11 55 00 37.94 -75.47     0
-------------------------------------------------------------------------------
NOTES: (1) BREAK FOR TURN AT 6 AT 100000; EST ARRIVAL AT 6 ASSUMING CONSTANT
COURSE. (2) ON INBOUND LEG ARRIVAL WFF ESTIMATED. (3) LAST ALT FILE POSITION
ESTIMATED ONLY ROUGHLY.
```

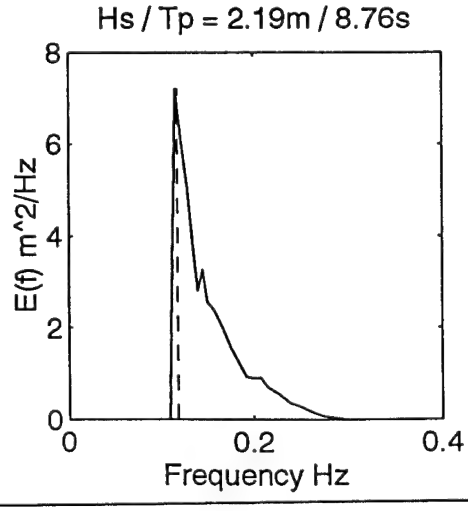

ROWS S0216_01
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 10.90; md/pd = 89/84

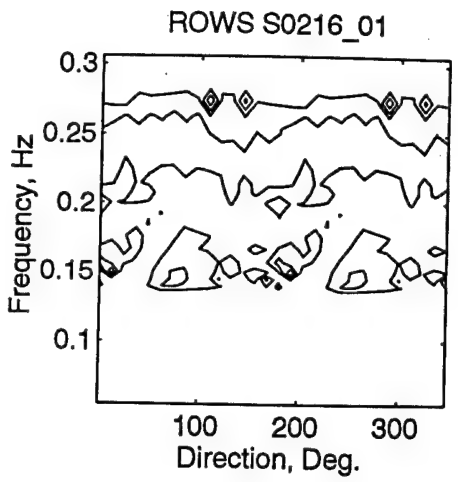

Hs / Tp = 1.13m / 7.60s
E(f) m^2/Hz
2
1.5
1
0.5
0
0 0.2 0.4
Frequency Hz

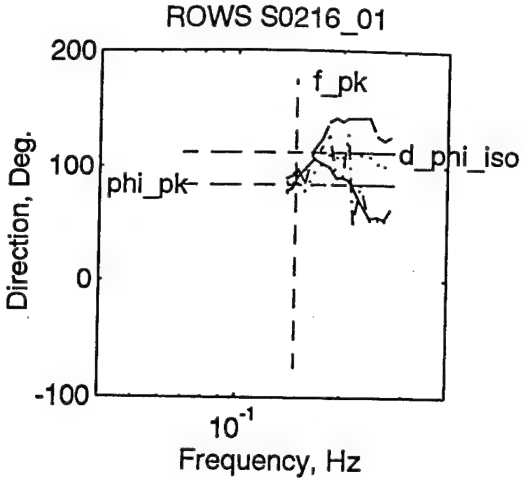

ROWS S0216_02
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 12.108; md/pd = 97/95

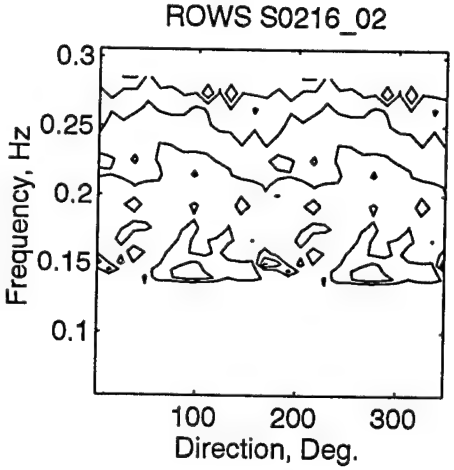

Hs / Tp = 2.14m / 7.63s
E(f) m^2/Hz
4
3
2
1
0
0 0.2 0.4
Frequency Hz

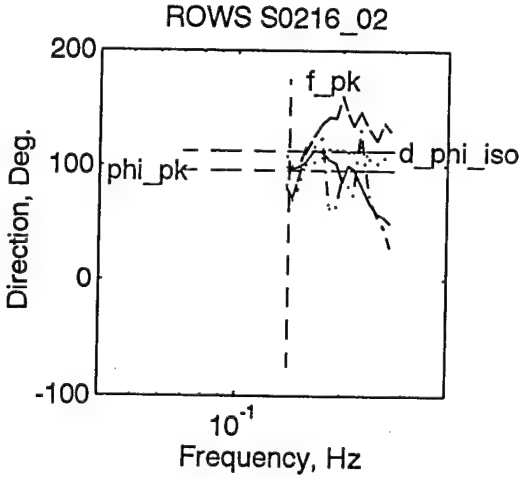

ROWS S0216_03
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 14.122; md/pd = 106/109

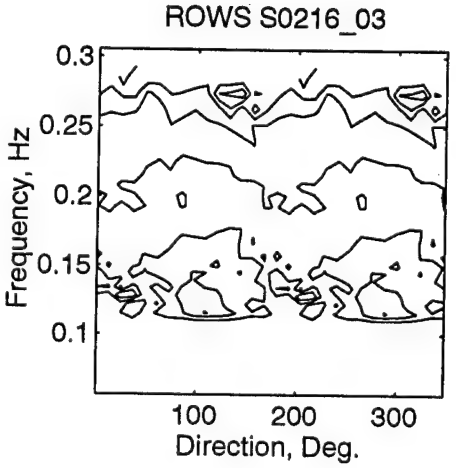

Hs / Tp = 2.19m / 8.76s
E(f) m^2/Hz
8
6
4
2
0
0 0.2 0.4
Frequency Hz

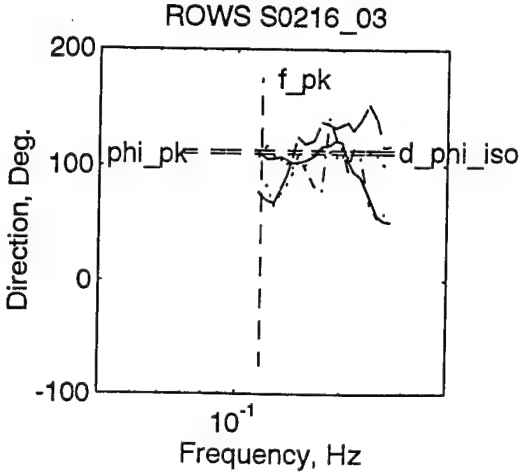

ROWS S0216_01
0.3
0.25
0.2
0.15
0.1
Frequency, Hz
100
200
300
Direction, Deg.

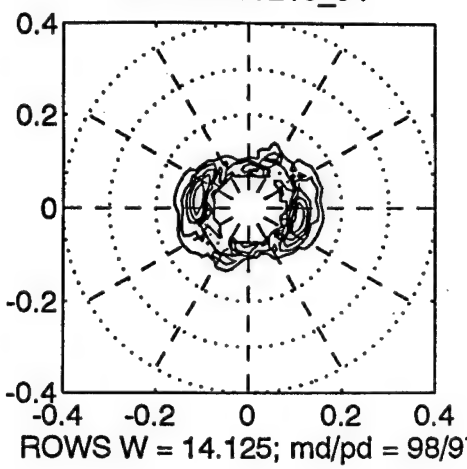

ROWS S0216_01
200
100
0
-100
Direction, Deg.
f_pk
phi_pk
d_phi_iso
10^{-1}
Frequency, Hz

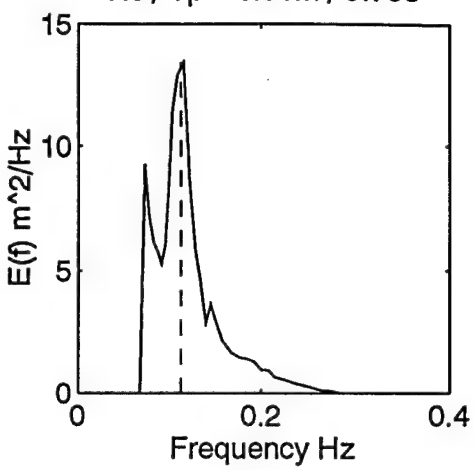

ROWS S0216_02
0.3
0.25
0.2
0.15
0.1
Frequency, Hz
100
200
300
Direction, Deg.

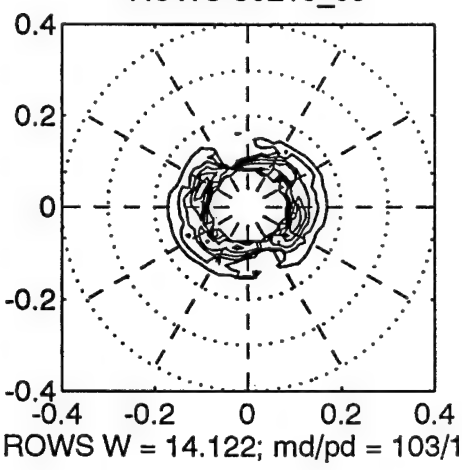

ROWS S0216_02
200
100
0
-100
Direction, Deg.
f_pk
phi_pk
d_phi_iso
10^{-1}
Frequency, Hz

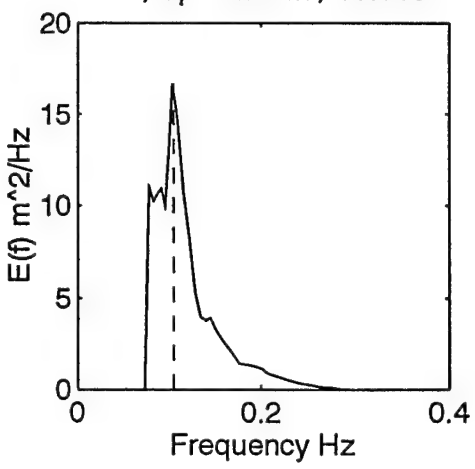

ROWS S0216_03
0.3
0.25
0.2
0.15
0.1
Frequency, Hz
100
200
300
Direction, Deg.

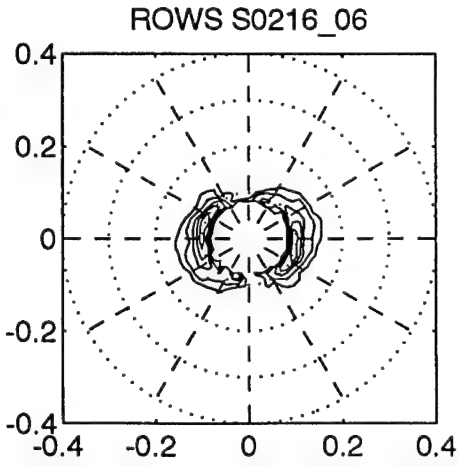

ROWS S0216_03
200
100
0
-100
Direction, Deg.
f_pk
phi_pk
d_phi_iso
10^{-1}
Frequency, Hz

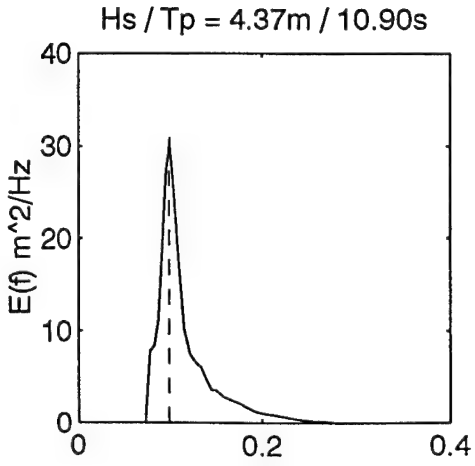

ROWS S0216_04
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 14.125; md/pd = 98/97

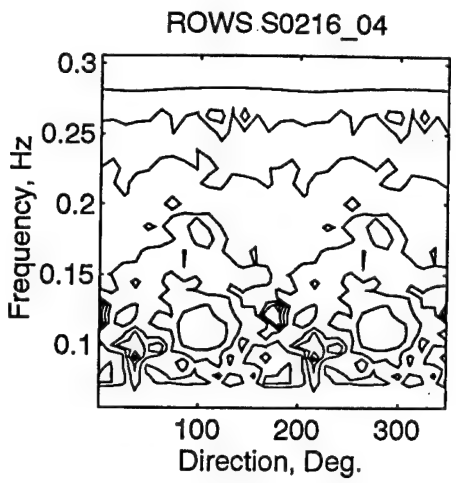

Hs / Tp = 3.31m / 9.79s
15
10
5
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz

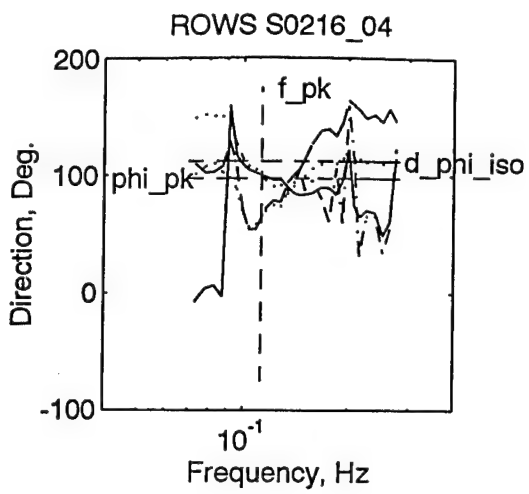

ROWS S0216_05
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 14.122; md/pd = 103/115

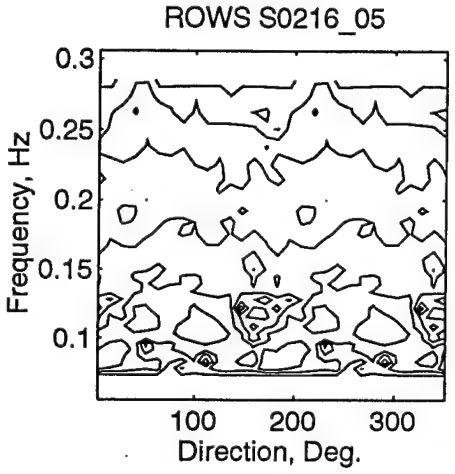

Hs / Tp = 4.32m / 10.86s
20
15
10
5
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz

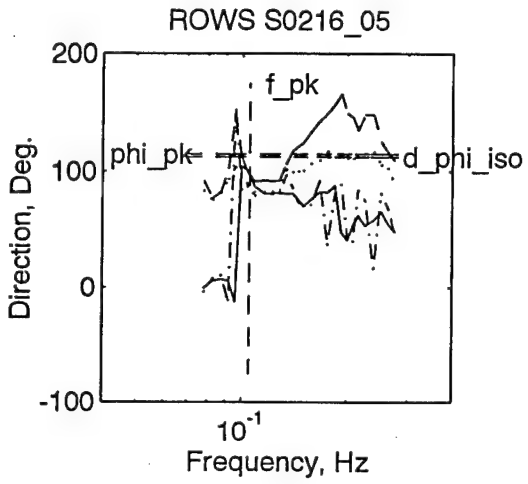

ROWS S0216_06
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 13.115; md/pd = 98/108

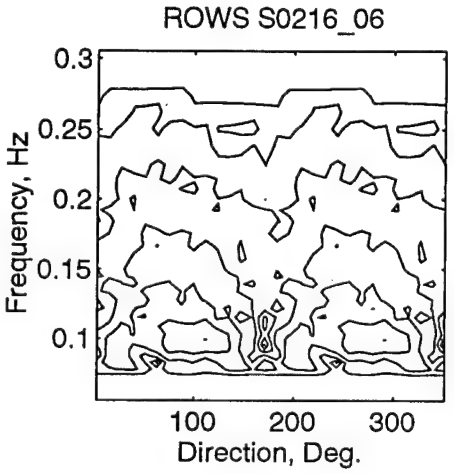

Hs / Tp = 4.37m / 10.90s
40
30
20
10
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz

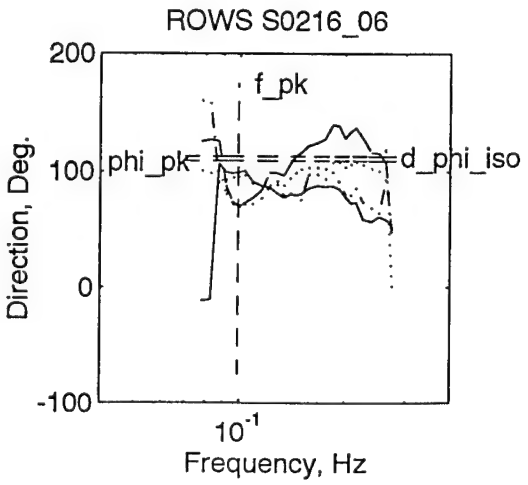

ROWS S0216_04
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

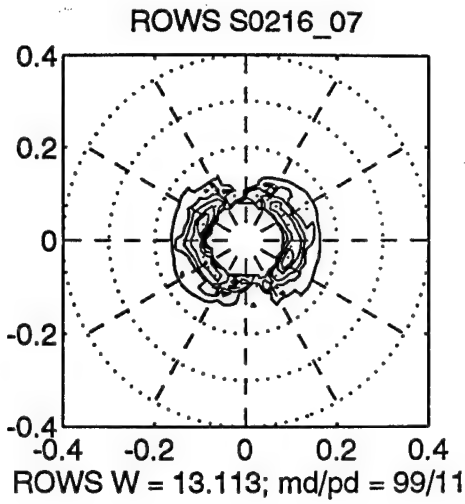

ROWS S0216_04
Direction, Deg.
200
100
0
-100
f_pk
phi_pk
d_phi_iso
10^{-1}
Frequency, Hz


ROWS S0216_05
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

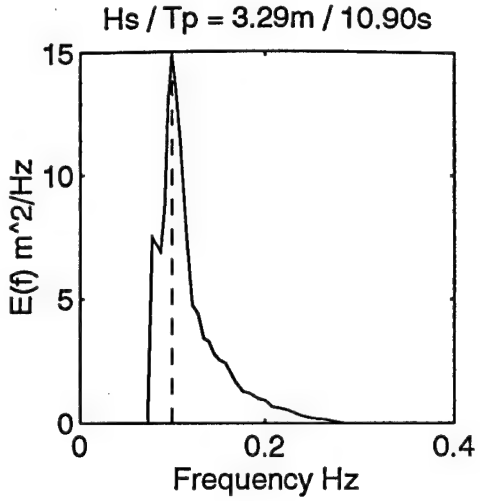

ROWS S0216_05
Direction, Deg.
200
100
0
-100
f_pk
phi_pk
d_phi_iso
10^{-1}
Frequency, Hz

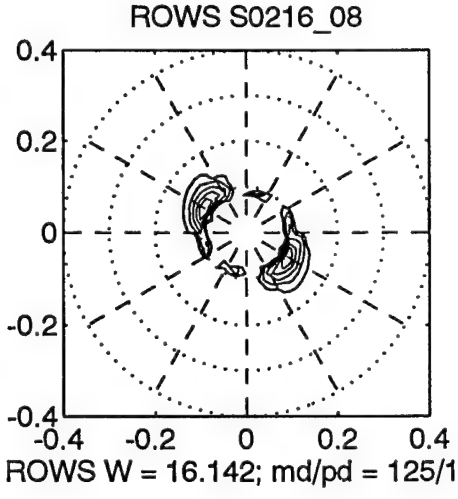

ROWS S0216_06
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.


ROWS S0216_06
Direction, Deg.
200
100
0
-100
f_pk
phi_pk
d_phi_iso
10^{-1}
Frequency, Hz

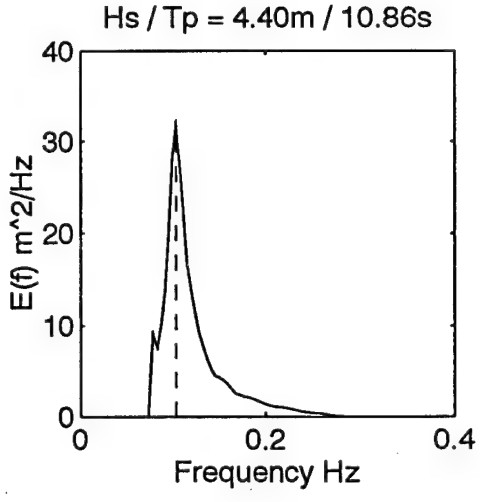


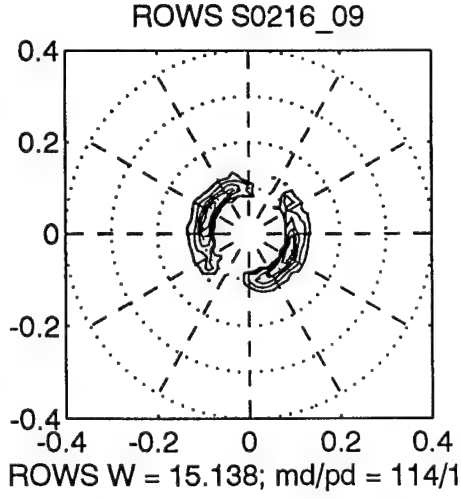
ROWS W = 13.113; md/pd = 99/111



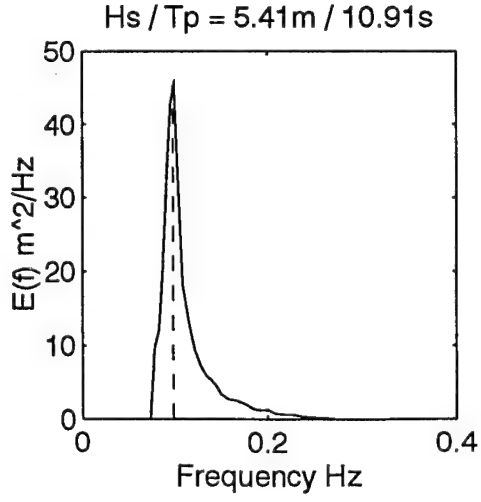


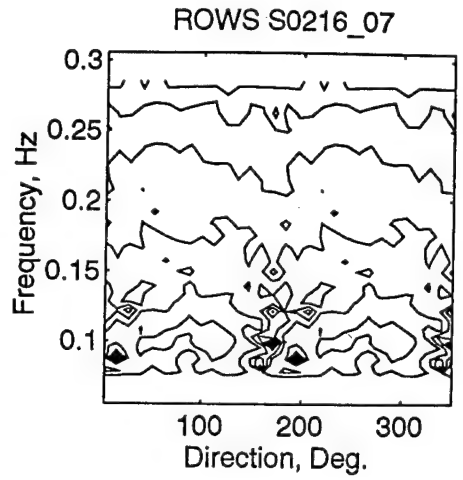
ROWS W = 16.142; md/pd = 125/121

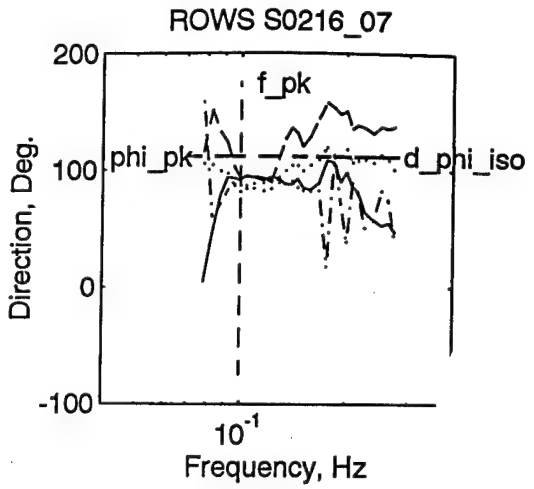


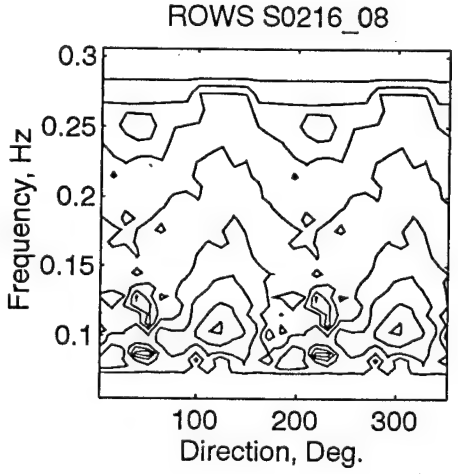


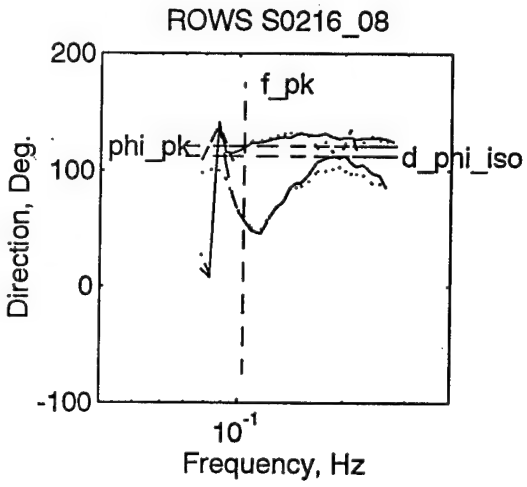
ROWS W = 15.138; md/pd = 114/110

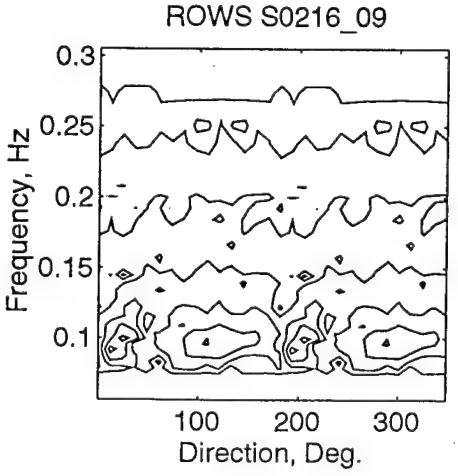


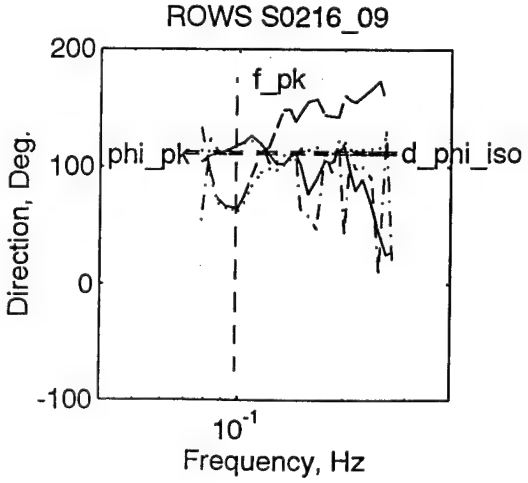

ROWS S0216_07
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

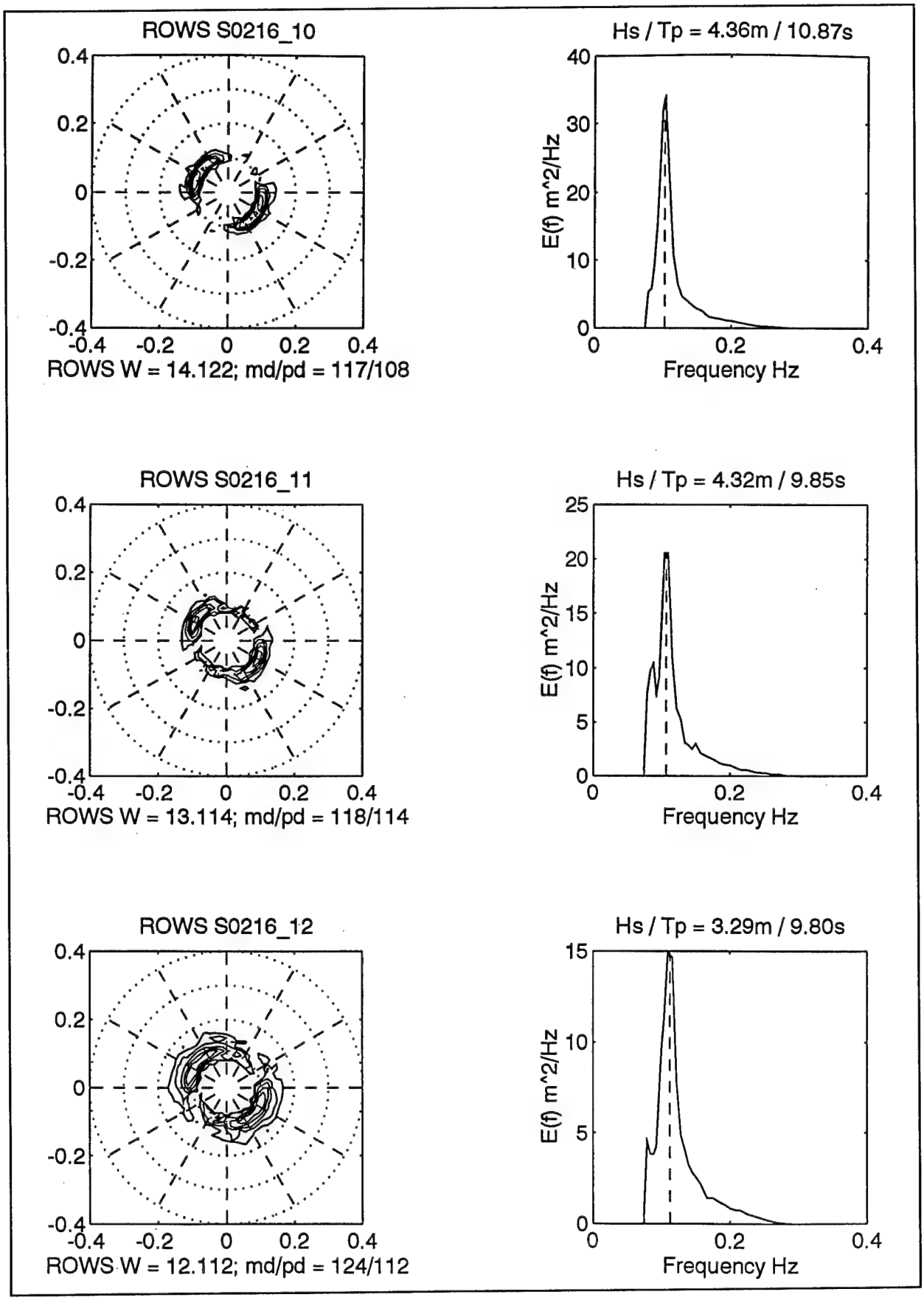

ROWS S0216_07
Direction, Deg.
200
100
0
-100
f_pk
phi_pk
d_phi_iso
10^{-1}
Frequency, Hz

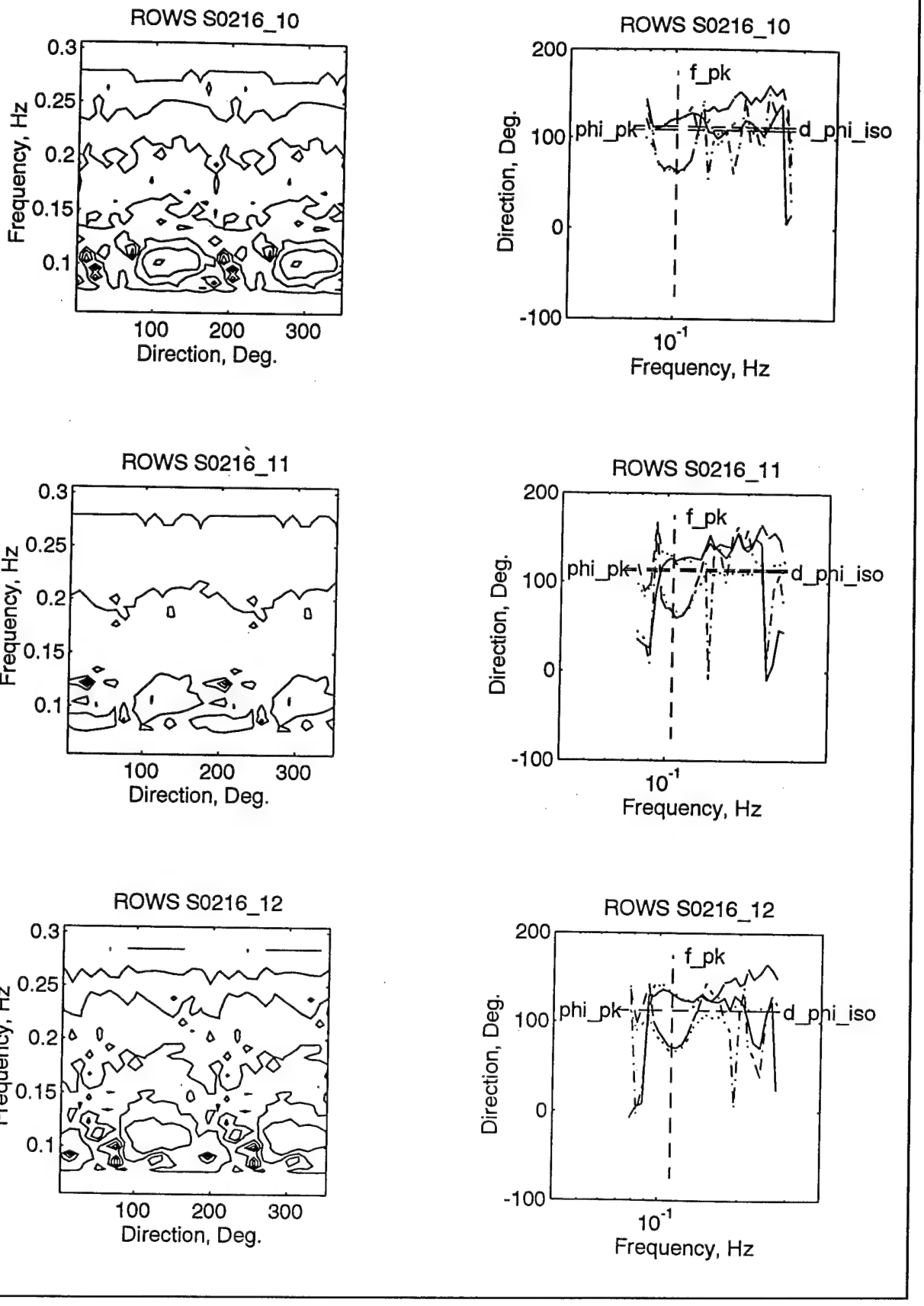

ROWS S0216_08
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

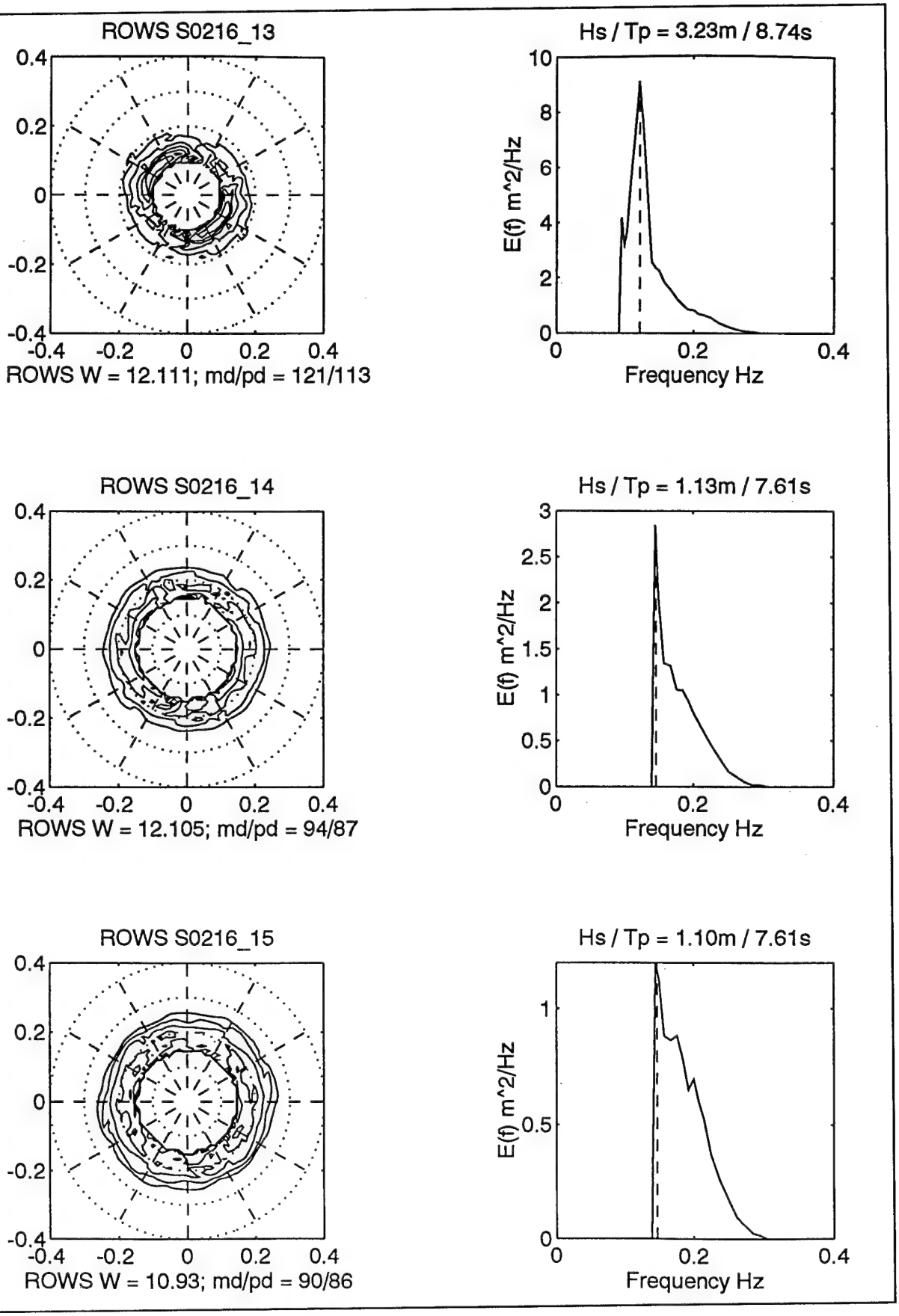

ROWS S0216_08
Direction, Deg.
200
100
0
-100
f_pk
phi_pk
d_phi_iso
10^{-1}
Frequency, Hz

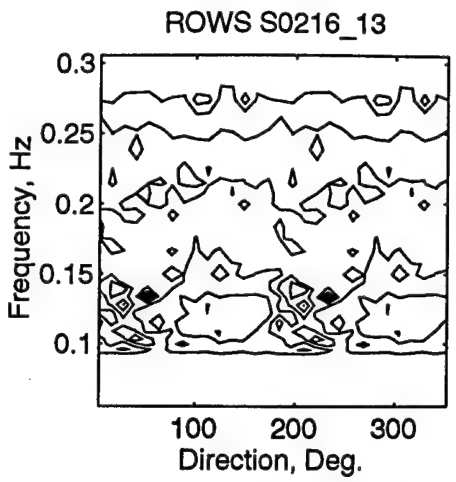

ROWS S0216_09
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

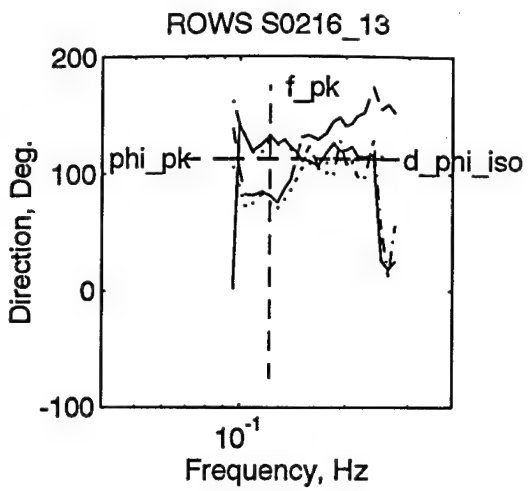

ROWS S0216_09
Direction, Deg.
200
100
0
-100
f_pk
phi_pk
d_phi_iso
10^{-1}
Frequency, Hz

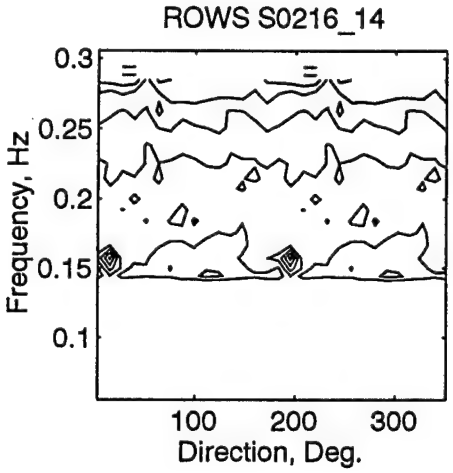

ROWS S0216_10
Hs / Tp = 4.36m / 10.87s
ROWS W = 14.122; md/pd = 117/108
E(f) m^2/Hz
Frequency Hz
ROWS S0216_11
Hs / Tp = 4.32m / 9.85s
ROWS W = 13.114; md/pd = 118/114
E(f) m^2/Hz
Frequency Hz
ROWS S0216_12
Hs / Tp = 3.29m / 9.80s
ROWS W = 12.112; md/pd = 124/112
E(f) m^2/Hz
Frequency Hz

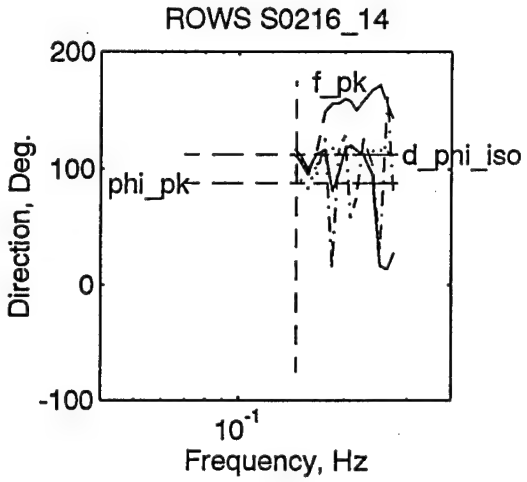

ROWS S0216_10
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.
ROWS S0216_10
Direction, Deg.
200
100
0
-100
f_pk
phi_pk
d_phi_iso
10^{-1}
Frequency, Hz
ROWS S0216_11
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.
ROWS S0216_11
Direction, Deg.
200
100
0
-100
f_pk
phi_pk
d_phi_iso
10^{-1}
Frequency, Hz
ROWS S0216_12
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.
ROWS S0216_12
Direction, Deg.
200
100
0
-100
f_pk
phi_pk
d_phi_iso
10^{-1}
Frequency, Hz

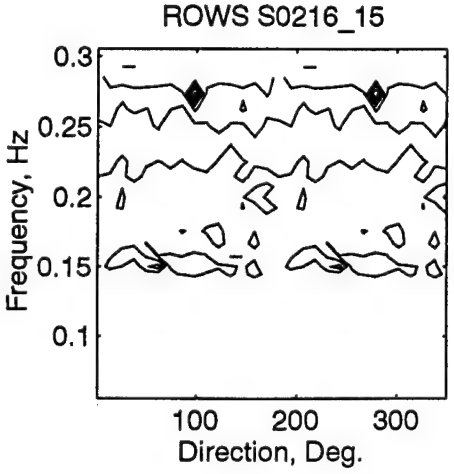

ROWS S0216_13
Hs / Tp = 3.23m / 8.74s
ROWS W = 12.111; md/pd = 121/113
E(f) m^2/Hz
Frequency Hz
ROWS S0216_14
Hs / Tp = 1.13m / 7.61s
ROWS W = 12.105; md/pd = 94/87
E(f) m^2/Hz
Frequency Hz
ROWS S0216_15
Hs / Tp = 1.10m / 7.61s
ROWS W = 10.93; md/pd = 90/86
E(f) m^2/Hz
Frequency Hz

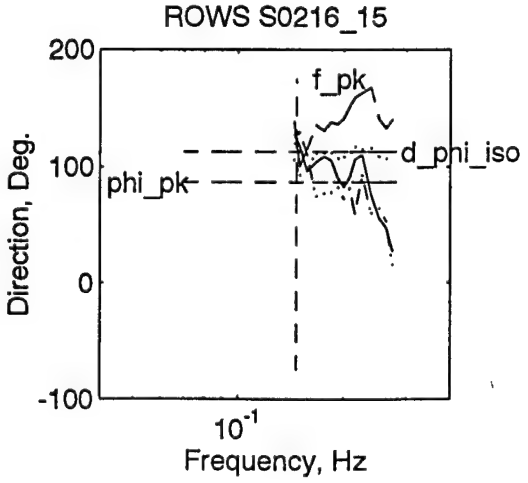

ROWS S0216_13
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

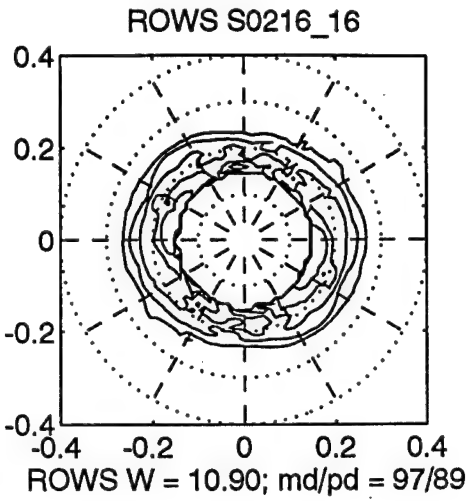

ROWS S0216_13
Direction, Deg.
200
100
0
-100
f_pk
phi_pk
d_phi_iso
10^{-1}
Frequency, Hz

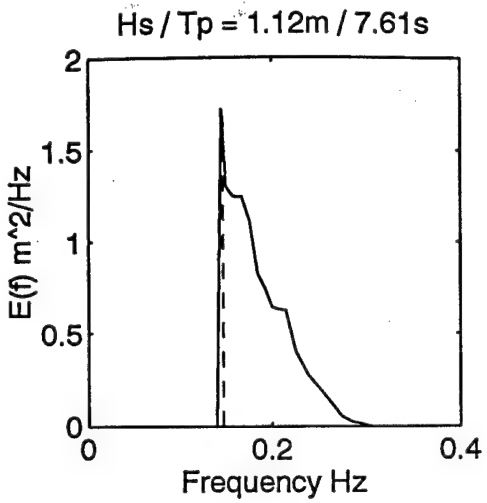

ROWS S0216_14
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

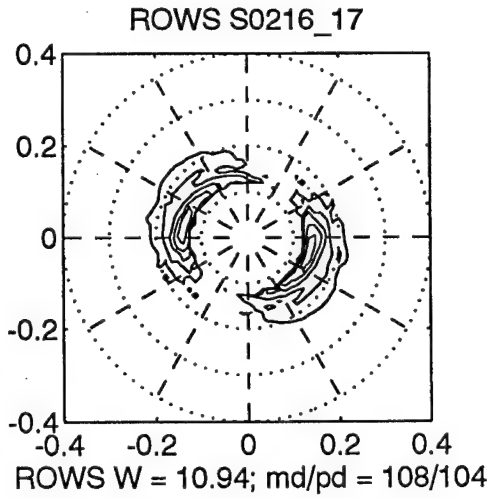

ROWS S0216_14
Direction, Deg.
200
100
0
-100
f_pk
phi_pk
d_phi_iso
10^{-1}
Frequency, Hz

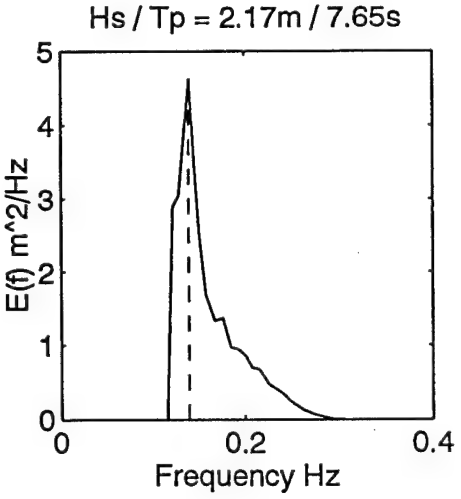

ROWS S0216_15
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

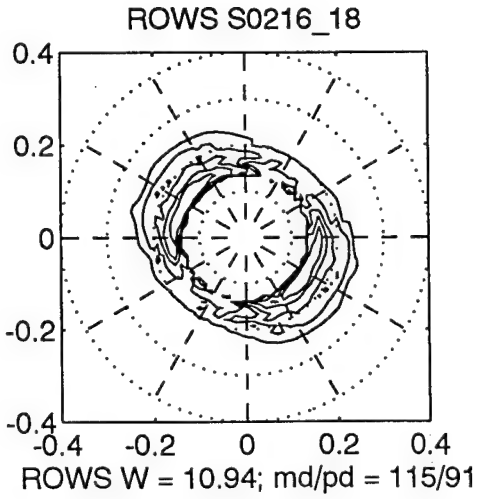

ROWS S0216_15
Direction, Deg.
200
100
0
-100
f_pk
phi_pk
d_phi_iso
10^{-1}
Frequency, Hz

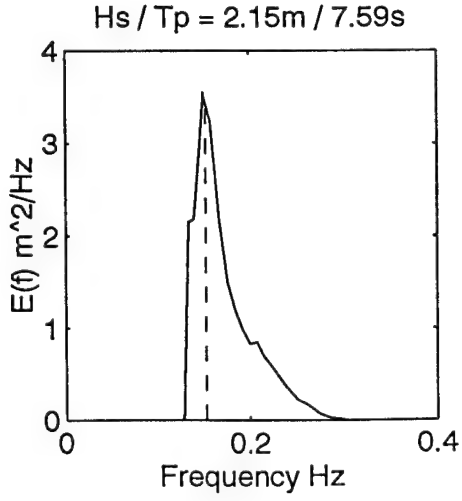

ROWS S0216_16
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 10.90; md/pd = 97/89

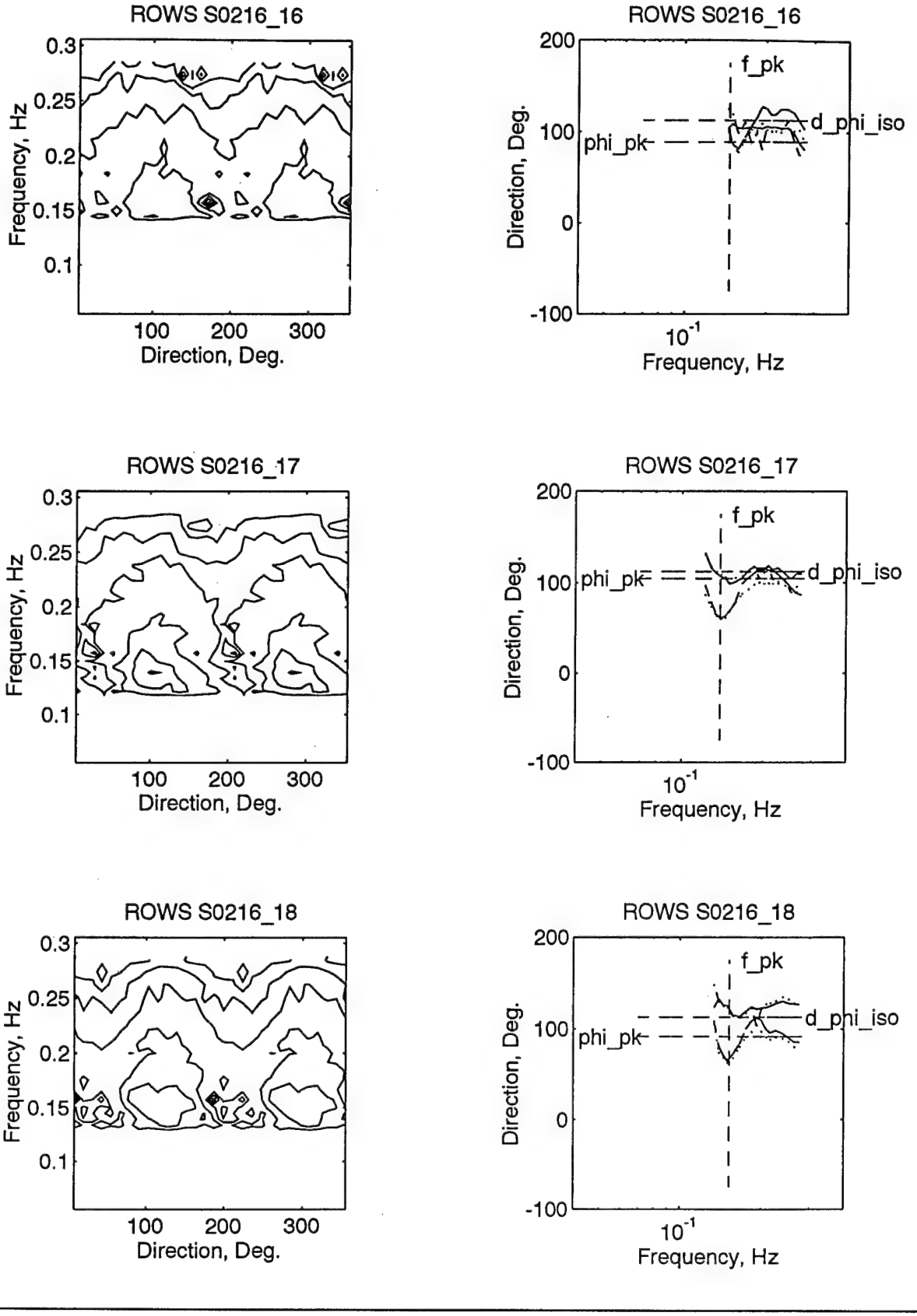

Hs / Tp = 1.12m / 7.61s
E(f) m^2/Hz
2
1.5
1
0.5
0
0 0.2 0.4
Frequency Hz

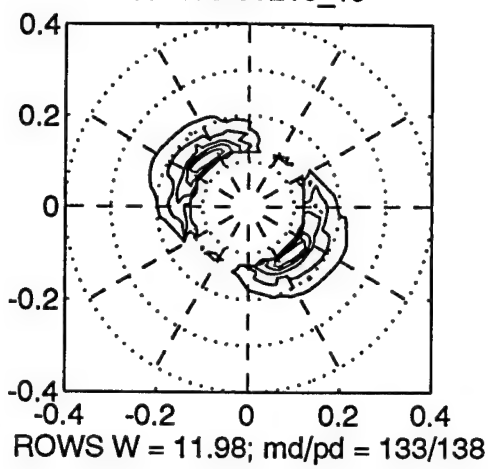

ROWS S0216_17
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 10.94; md/pd = 108/104


Hs / Tp = 2.17m / 7.65s
E(f) m^2/Hz
5
4
3
2
1
0
0 0.2 0.4
Frequency Hz

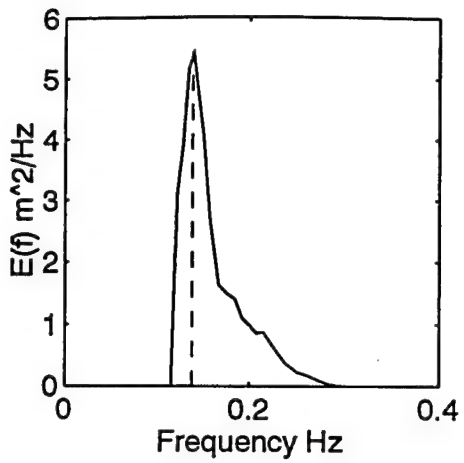

ROWS S0216_18
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 10.94; md/pd = 115/91

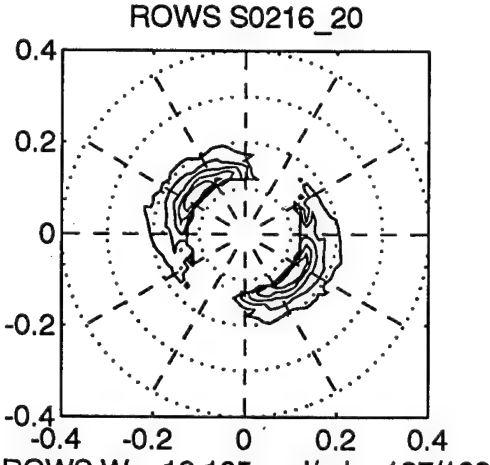

Hs / Tp = 2.15m / 7.59s
E(f) m^2/Hz
4
3
2
1
0
0 0.2 0.4
Frequency Hz


ROWS S0216_16
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.
ROWS S0216_16
Direction, Deg.
200
100
0
-100
f_pk
phi_pk
d_phi_iso
10^{-1}
Frequency, Hz
ROWS S0216_17
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.
ROWS S0216_17
Direction, Deg.
200
100
0
-100
f_pk
phi_pk
d_phi_iso
10^{-1}
Frequency, Hz
ROWS S0216_18
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.
ROWS S0216_18
Direction, Deg.
200
100
0
-100
f_pk
phi_pk
d_phi_iso
10^{-1}
Frequency, Hz

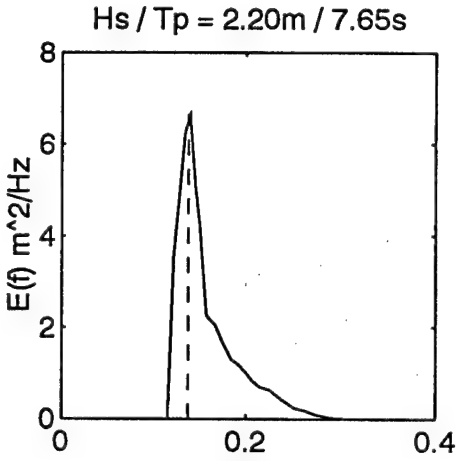


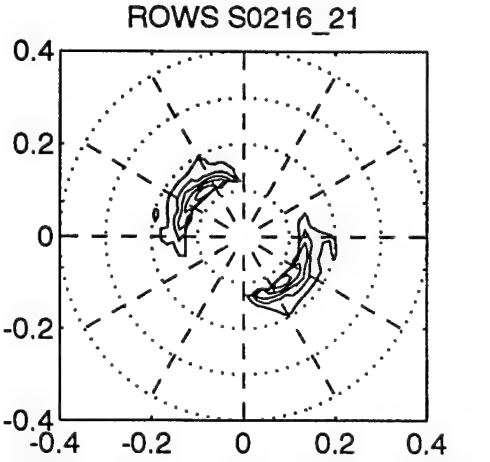
ROWS W = 11.98; md/pd = 133/138



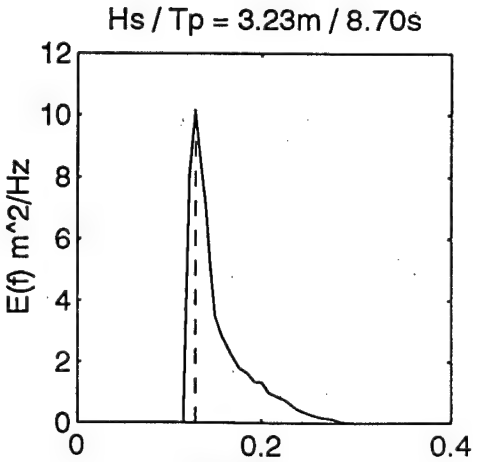


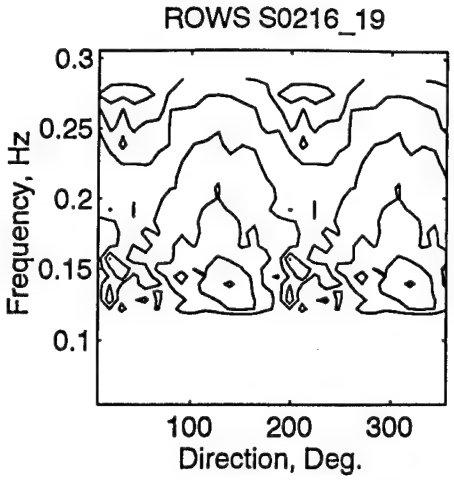
ROWS W = 12.105; md/pd = 127/128

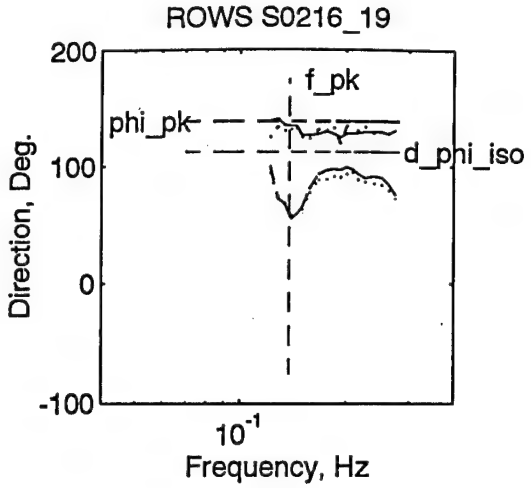


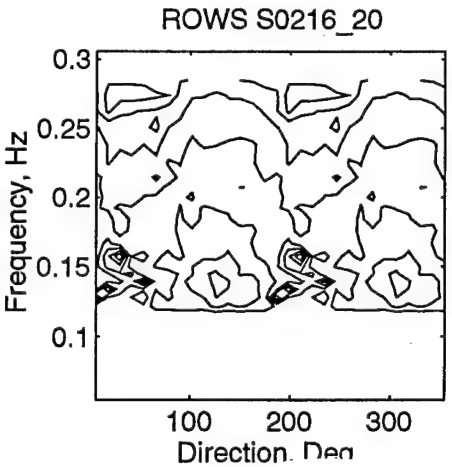


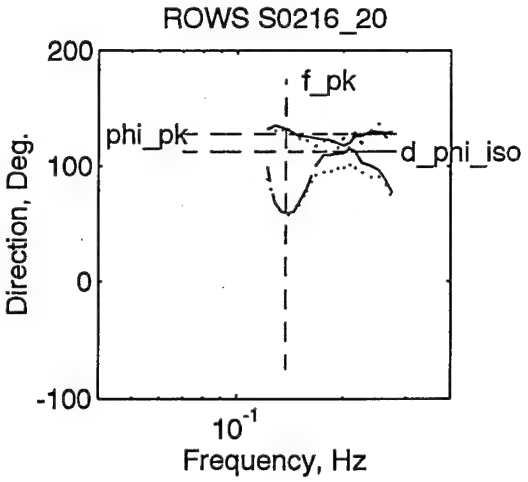
ROWS W = 13.114; md/pd = 129/138

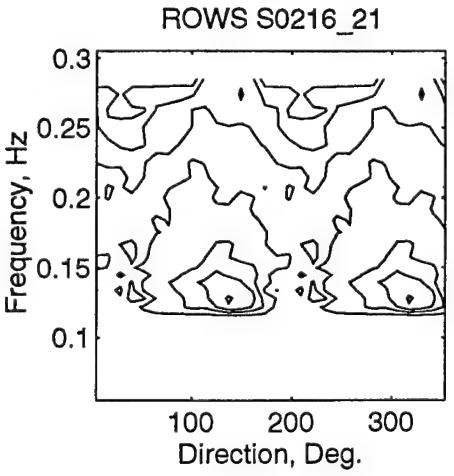


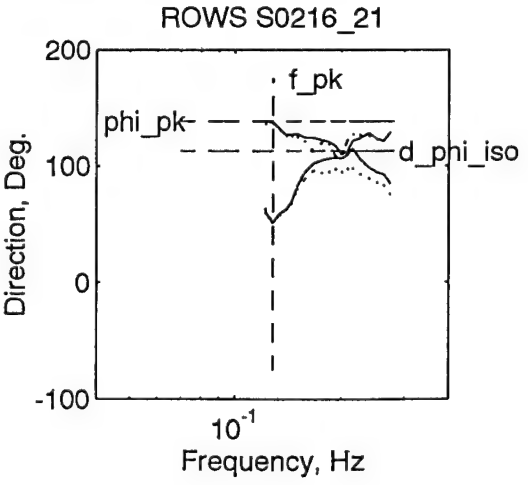

ROWS S0216_19
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.

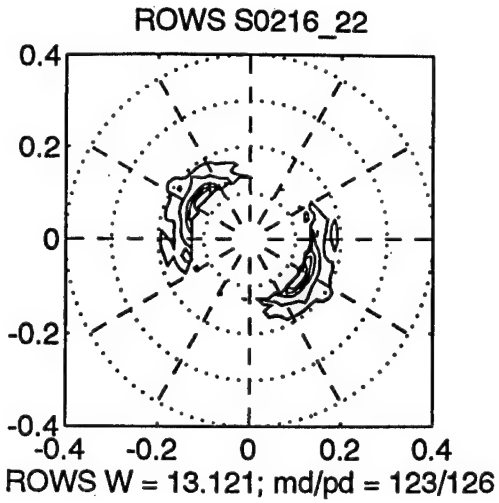

ROWS S0216_19
Direction, Deg.
200
100
0
-100
f_pk
phi_pk
d_phi_iso
10^{-1}
Frequency, Hz

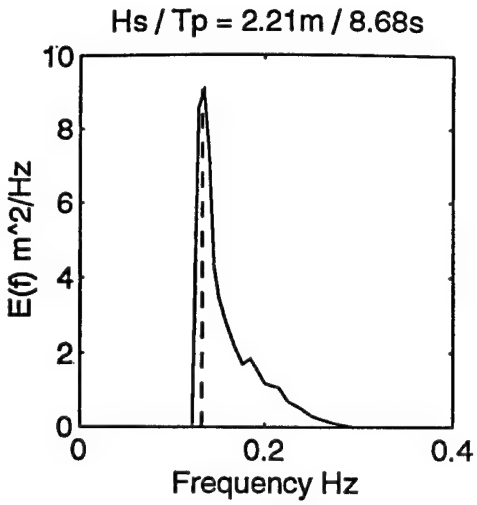

ROWS S0216_20
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg

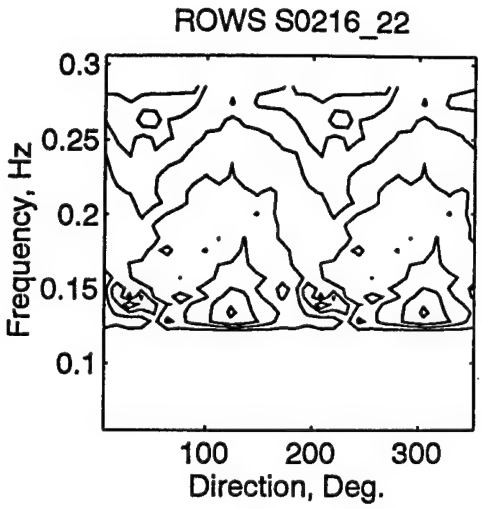

ROWS S0216_20
Direction, Deg.
200
100
0
-100
f_pk
phi_pk
d_phi_iso
10^{-1}
Frequency, Hz

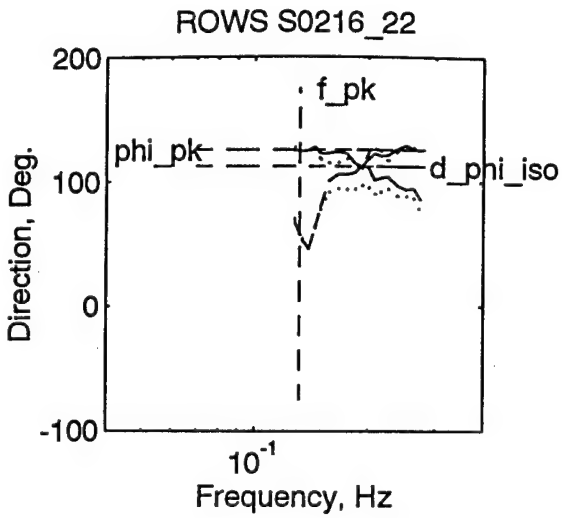

ROWS S0216_21
Frequency, Hz
0.3
0.25
0.2
0.15
0.1
100
200
300
Direction, Deg.


ROWS S0216_21
Direction, Deg.
200
100
0
-100
f_pk
phi_pk
d_phi_iso
10^{-1}
Frequency, Hz


ROWS S0216_22
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 13.121; md/pd = 123/126


Hs / Tp = 2.21m / 8.68s
10
8
6
4
2
0
E(f) m^2/Hz
0
0.2
0.4
Frequency Hz

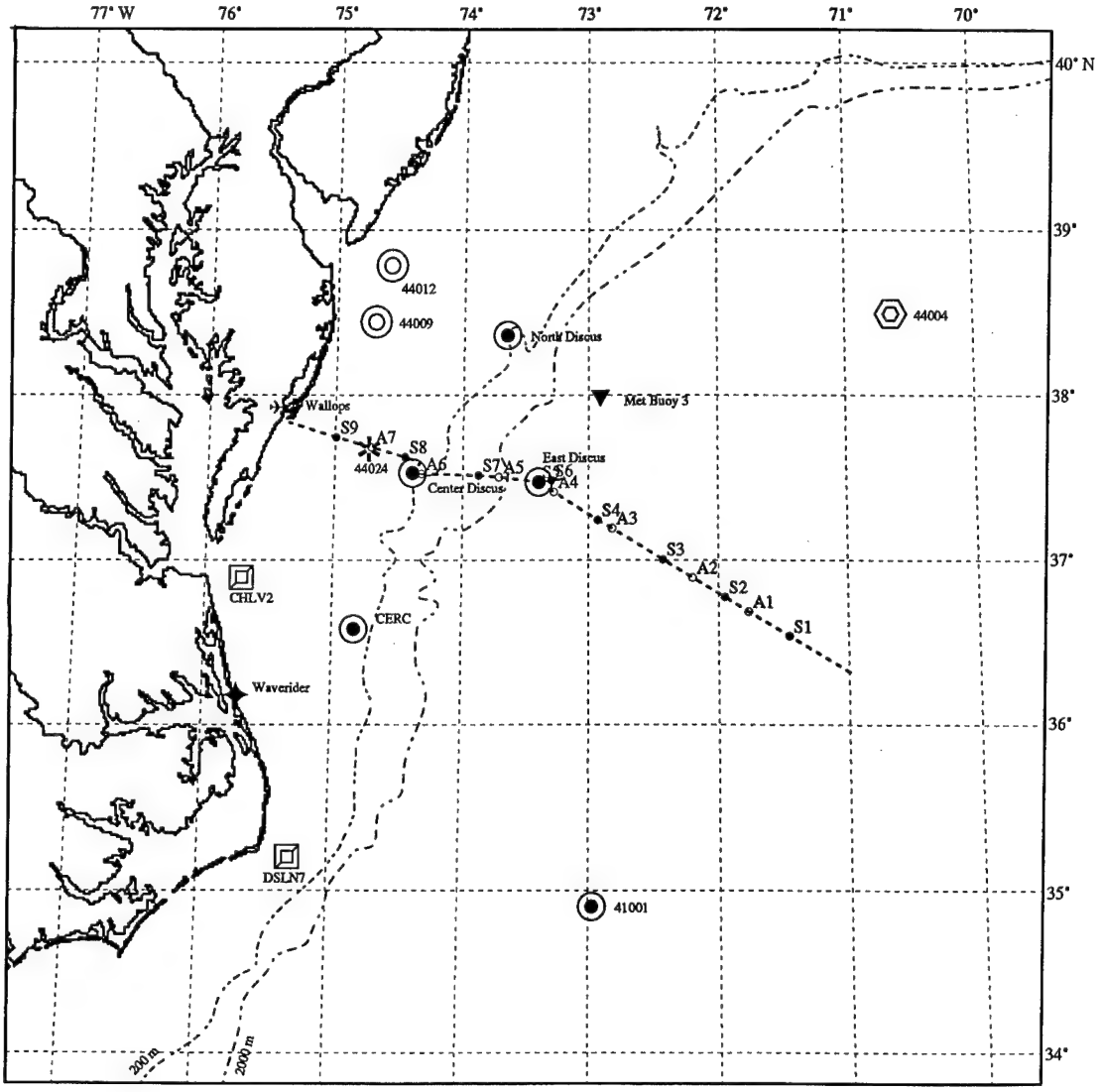

ROWS S0216_22
0.3
0.25
0.2
0.15
0.1
Frequency, Hz
100
200
300
Direction, Deg.


ROWS S0216_22
200
100
0
-100
Direction, Deg.
f_pk
phi_pk
d_phi_iso
10^-1
Frequency, Hz

Appendix E3: ROWS Spectra for IOP-3, 27 February - 7 March 1991

The ROWS directional spectra plots for the seven SWADE IOP-3 flights in this appendix are augmented with zoom plots for 5 March, the SWADE priority day. In the 5 March zoom plots, the maximum frequency is 0.2 Hz instead of 0.4 Hz. These plots help to better resolve the complex, trimodal structure of the swell on this day.

ROWS Flight
27 Feb 1991



Symbols

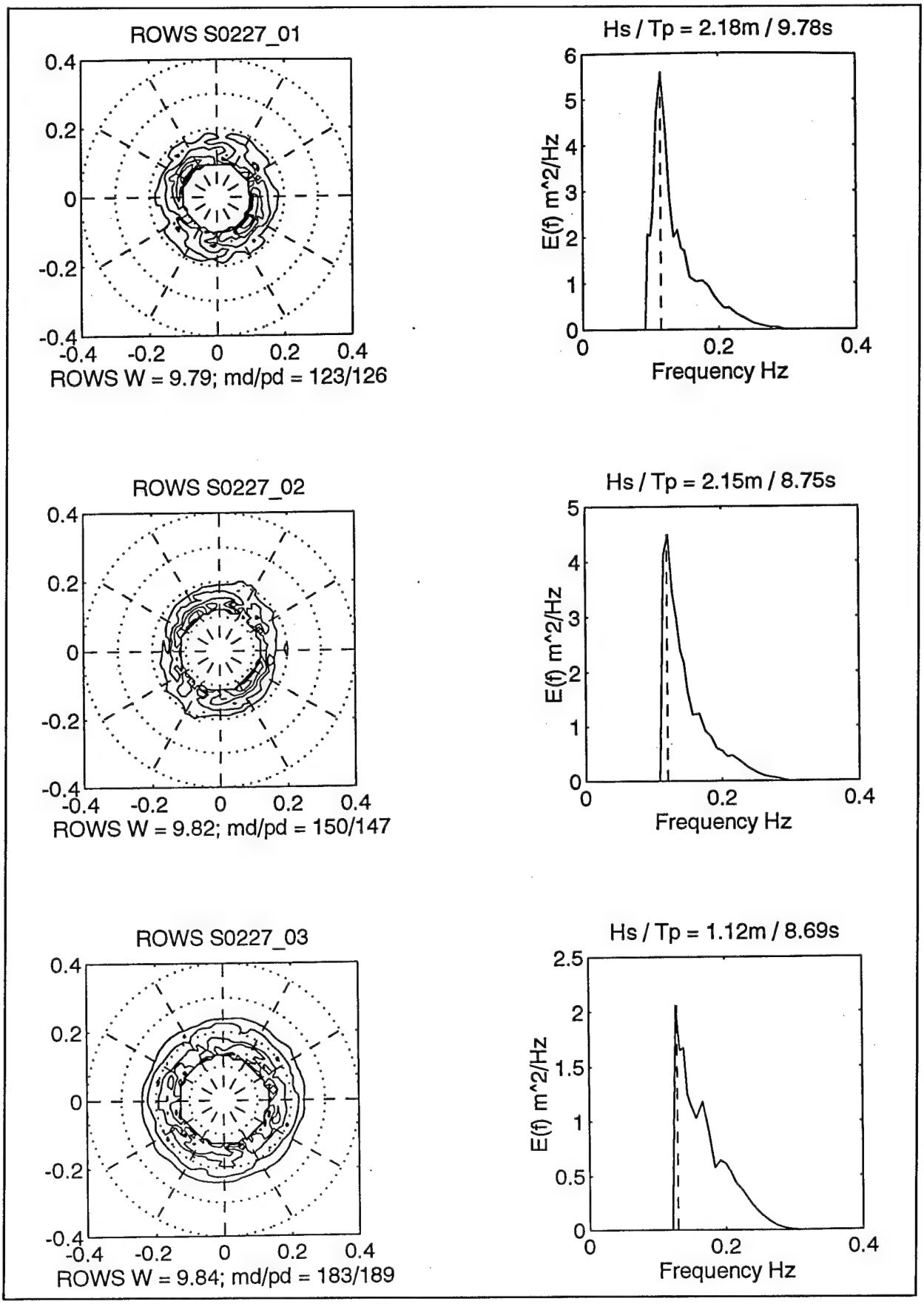
- Coastal Buoy
- 3m Discus Buoy
- 12m Discus Buoy
- 6m NORMAD Buoy
- 1m Met Buoy
- C-Man Station

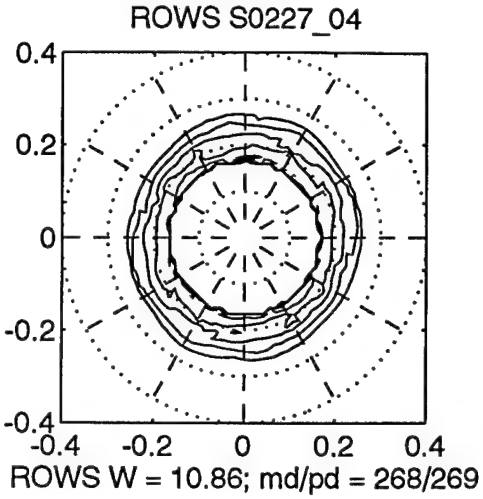
Lambert Conformal Projection
Aug93

ROWS SWADE FLIGHT NAVIGATION AND FILE DATA
FEB 27, 1991

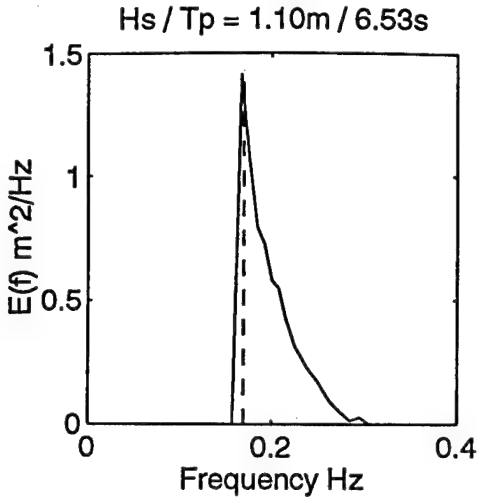
TAPE2/2 FILE	POS FIX	ROWS MODE	BUOY/ WP	EST HH	MM	SS	LAT	LON	ALT	SPD M/S	HDG TRU	PC-TIC START	REC # START	0 DEG DELTA	LEN MB
	0	0	TP1'				36.32	-71.00	7625	135	291				
S01	0	1		19	18	06	36.54	-71.46	7625	135	291	002419	6401	418	12
	1	0		19	19	13	36.58	-71.54	7625	135	291				
A01	0	2		19	22	06	36.69	-71.77	7625	135	291	002924	34901		1
S02	0	1		19	24	21	36.78	-71.95	7625	135	291	003042	40401	902	12
A02	0	2		19	28	36	36.90	-72.20	7625	135	291	003553	70201		1
S03	0	1		19	30	36	37.01	-72.43	7625	135	291	003657	75201	356	12
A03	0	2		19	35	36	37.20	-72.82	7625	135	291	004251	107201		1
S04	0	1		19	37	02	37.25	-72.93	7625	135	291	004323	108801	438	12
A04	0	2		19	41	36	37.42	-73.28	7625	135	291	004850	140301		1
S05	1	3	DIS-E	19	42	34	37.48	-73.40	7625	200	032	004924	142801	381	6
	1	0		19	54	02	37.50	-73.19	7625	131	269				
S06	0	1		19	55	03	37.49	-73.30	7625	131	269	010121	212201	553	12
	1	0	DIS-E	19	56	05	37.48	-73.40	7625	131	269				
A05	0	2		19	59	50	37.51	-73.71	7625	130	272	010705	245401		1
S07	1	1		20	01	47	37.52	-73.87	7625	130	272	010806	250101	968	12
A06	0	2		20	05	40	37.53	-74.32	7625	130	272	011251	277301		1
	1	0	DIS-C	20	07	23	37.53	-74.39	7625	130	272				
	0	0	TEMP				37.60	-74.33	7625						
S08	1	1		20	20	48	37.63	-74.45	7625	138	283	012706	347401	215	12
A07	1	2	EXP	20	23	24	37.69	-74.72	7625	138	283	013031	366301		1
S09	0	1		20	26	24	37.75	-75.00	7625	138	283	013234	388001	32	12
	0	0	COAST	20	29	03	37.84	-75.37							

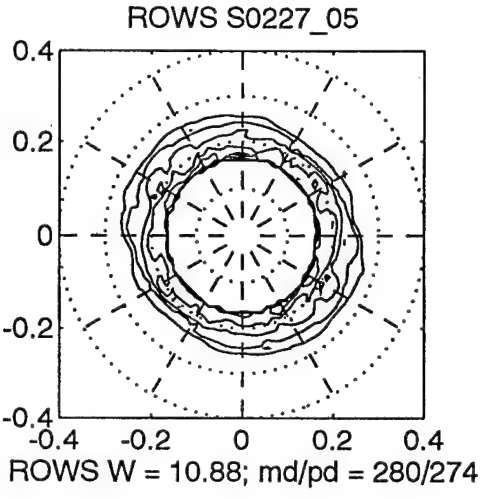
NOTES: ALL DATA ON REVERSE COURSE ON TAPE 2.


ROWS S0227_01
Hs / Tp = 2.18m / 9.78s
ROWS W = 9.79; md/pd = 123/126
E(f) m^2/Hz
Frequency Hz
ROWS S0227_02
Hs / Tp = 2.15m / 8.75s
ROWS W = 9.82; md/pd = 150/147
E(f) m^2/Hz
Frequency Hz
ROWS S0227_03
Hs / Tp = 1.12m / 8.69s
ROWS W = 9.84; md/pd = 183/189
E(f) m^2/Hz
Frequency Hz

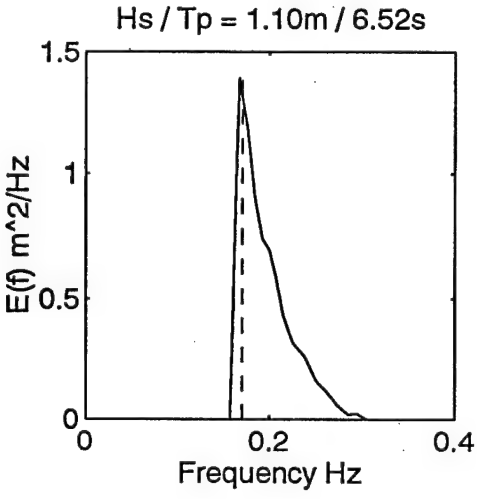


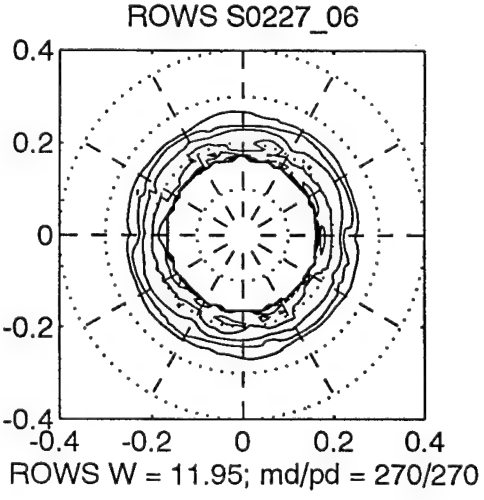
ROWS W = 10.86; md/pd = 268/269



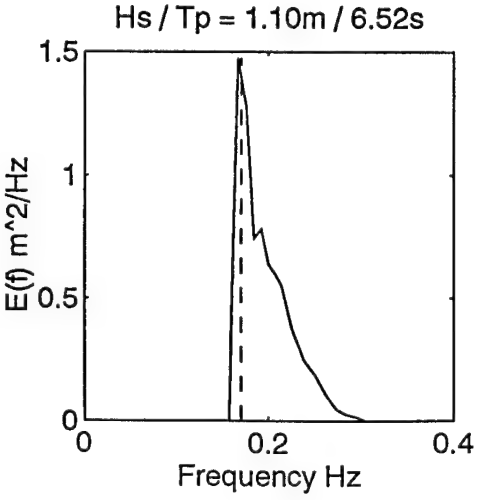


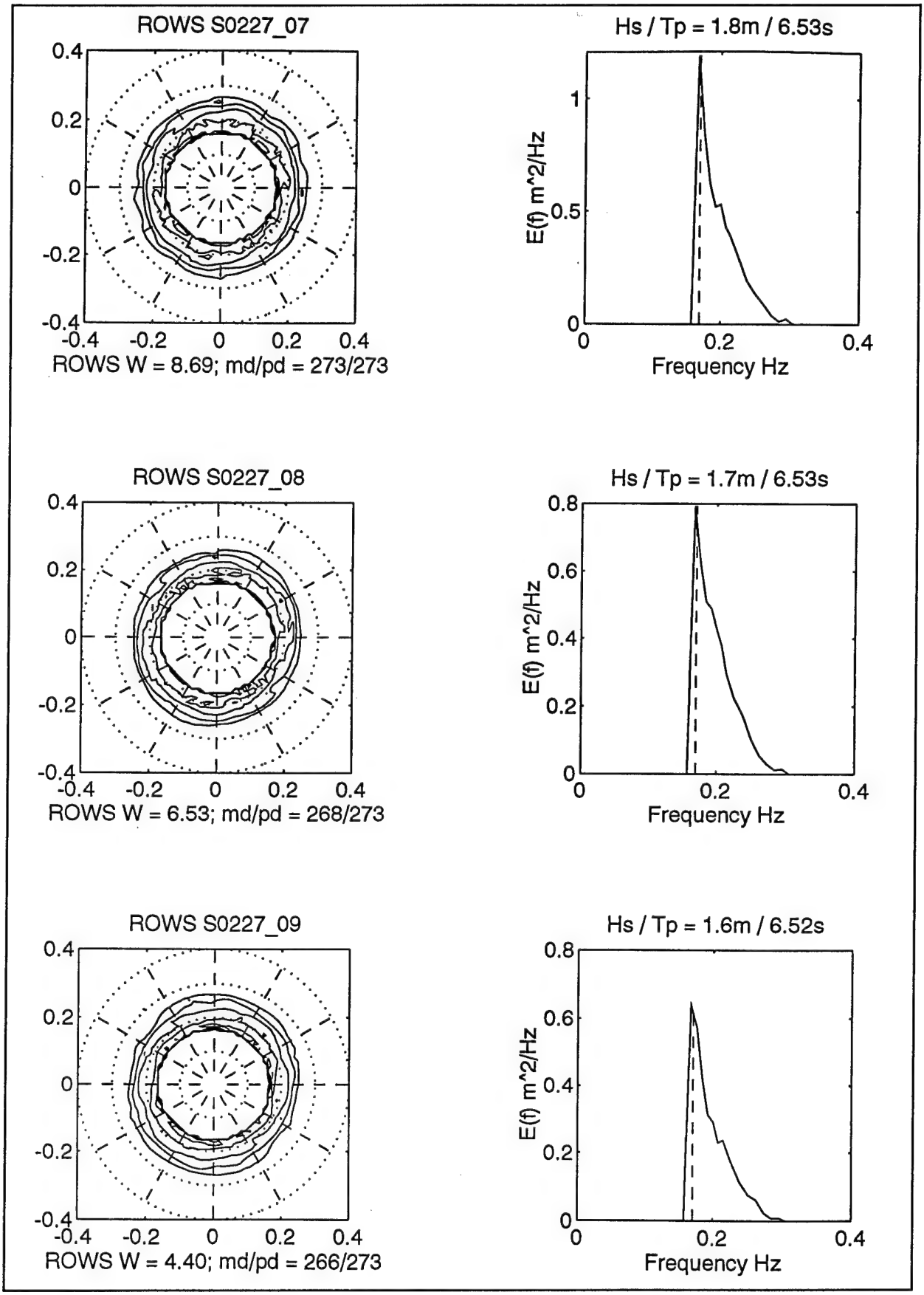
ROWS W = 10.88; md/pd = 280/274

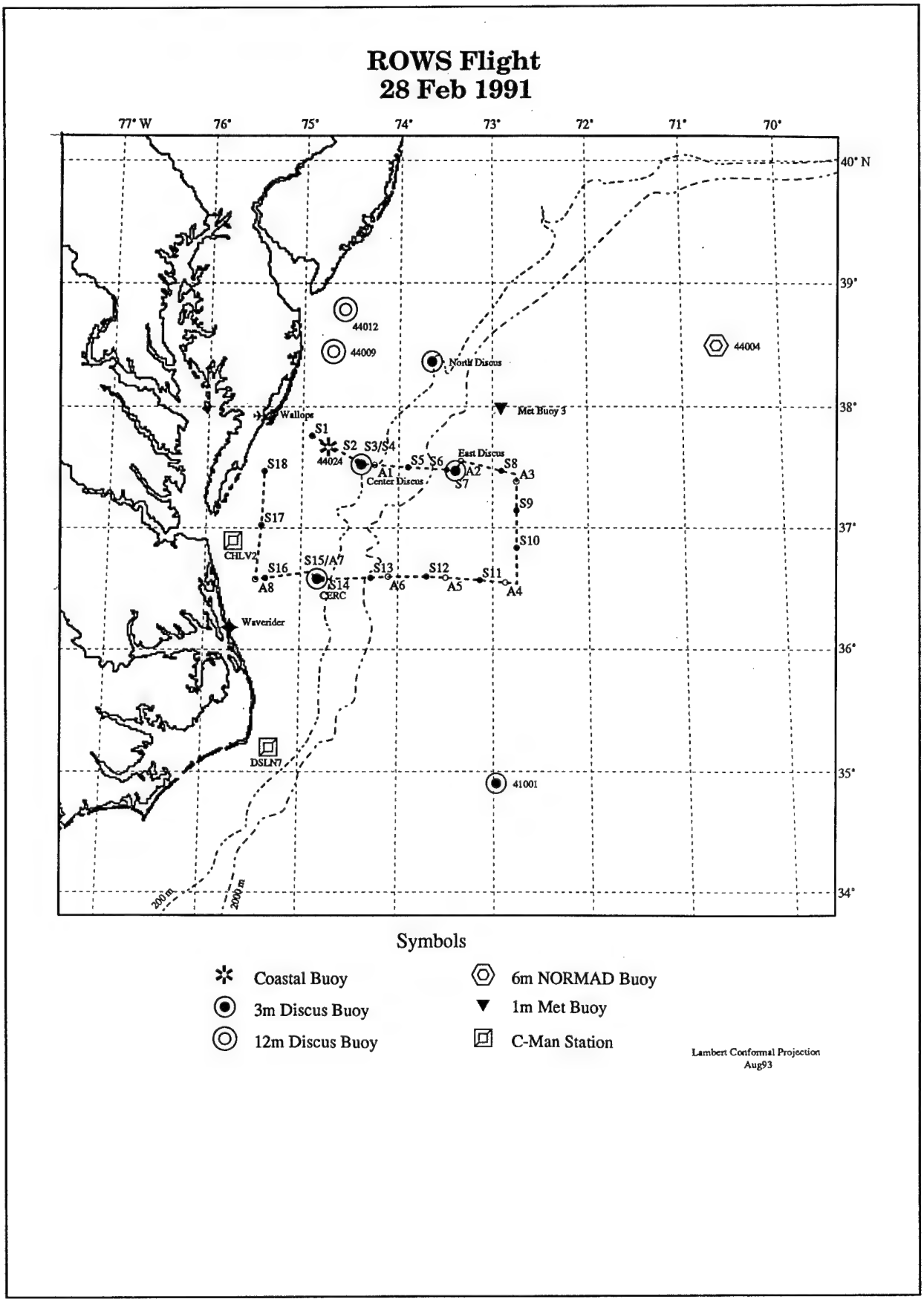




ROWS W = 11.95; md/pd = 270/270



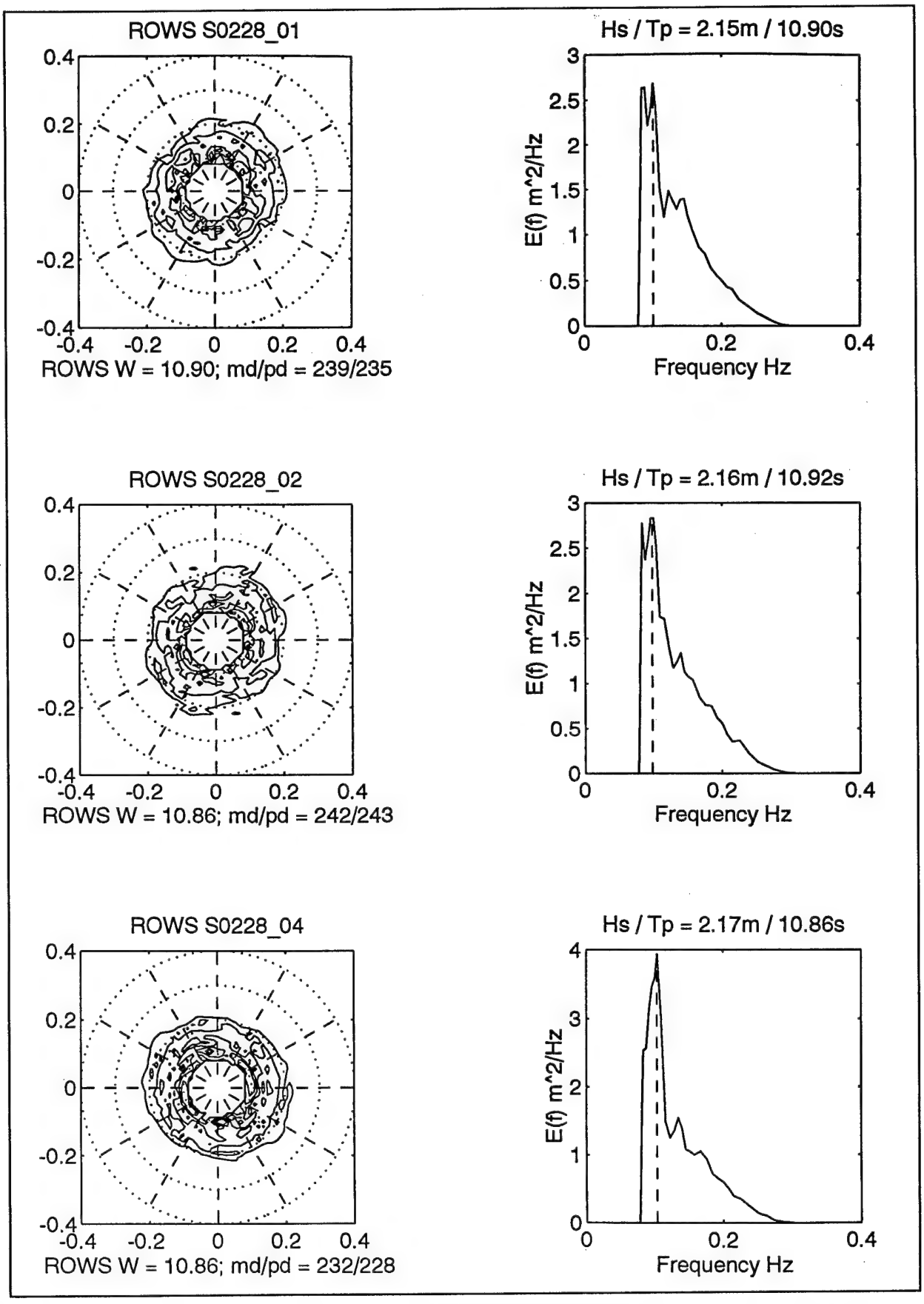

ROWS S0227_07
Hs / Tp = 1.8m / 6.53s
ROWS W = 8.69; md/pd = 273/273
E(f) m^2/Hz
Frequency Hz
ROWS S0227_08
Hs / Tp = 1.7m / 6.53s
ROWS W = 6.53; md/pd = 268/273
E(f) m^2/Hz
Frequency Hz
ROWS S0227_09
Hs / Tp = 1.6m / 6.52s
ROWS W = 4.40; md/pd = 266/273
E(f) m^2/Hz
Frequency Hz

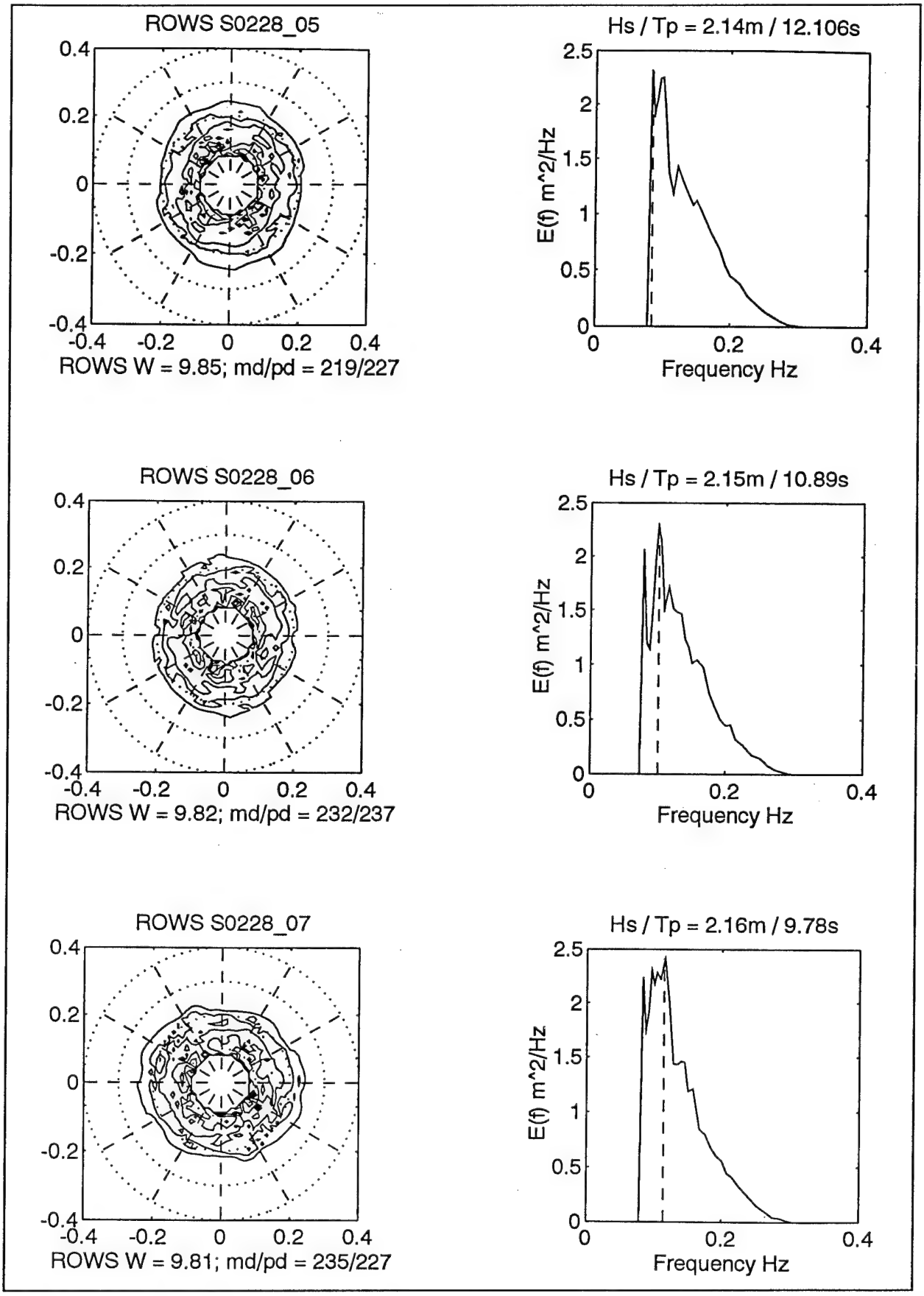

ROWS Flight
28 Feb 1991
77° W
76°
75°
74°
73°
72°
71°
70°
40° N
39°
38°
37°
36°
35°
34°
44012
44009
44004
North Discus
Met Buoy 3
Wallops
S1
S2
S3/S4
44024
A1
Center Discus
S5
S6
East Discus
A2
S7
S8
A3
S9
S10
S18
S17
CHLV2
S16
A8
S15/A7
S14
CERC
S13
A6
S12
A5
S11
A4
Waverider
DSLN7
41001
200 m
2000 m
Symbols
Coastal Buoy
3m Discus Buoy
12m Discus Buoy
6m NORMAD Buoy
1m Met Buoy
C-Man Station
Lambert Conformal Projection
Aug93

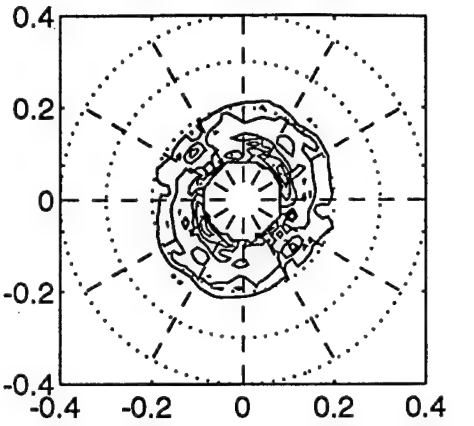
ROWS SWADE FLIGHT NAVIGATION AND FILE DATA
FEB 28, 1991

TAPE1/1 FILE	POS FIX	ROWS MODE	BUOY/ WP	EST HH	MM	SS	LAT	LON	ALT	SPD M/S	HDG TRU	PC-TIC START	REC # START	0 DEG DELTA	LEN MI
	1	0	SWL				38.13	-75.47							
S01	0	1		16	29	05	37.77	-74.91	5338	199	125	042730	7201	877	12
	1	0	EXP	16	30	45	37.69	-74.72	5338	199	125				
S02	0	1	DIS-C	16	33	10	37.56	-74.43	5338	199	125	043134	31601	417	12
	1	0	DIS-C	16	33	44	37.54	-74.39	5338	199	125				
S03	0	3	DIS-C	16	35	22	37.54	-74.39	5338	142	235	043416	47801	176	6
S04	0	3	DIS-C	16	37	55	37.54	-74.39	5338	185	032	043648	63001	941	6
A01	0	2		16	42	10	37.53	-74.25	5338	201	090	044130	90101		1
S05	0	1		16	44	45	37.51	-73.90	5338	201	090	044305	98901	163	12
S06	0	1	DIS-E	16	47	50	37.49	-73.49	5338	201	090	044613	117701	318	12
	1	0	DIS-E	16	48	30	37.48	-73.40	5338	201	090				
S07	0	3	DIS-E	16	52	20	37.48	-73.40	5338	160	193	045114	147701	241	6
A02	0	2		16	56	00	37.56	-73.34	5338	201	107	045519	169301		1
	1	0		16	57	20	37.53	-73.16	5338	201	107				
S08	0	1		16	58	00	37.48	-72.91	5338	201	107	045624	175101	964	12
	1	0	TPN	16	59	01	37.45	-72.75	5338						
A03	0	2		17	00	30	37.39	-72.75	5338	165	191	045948	195501		1
	1	0		17	02	12	37.24	-72.75	5338	165	191				
S09	0	1		17	03	12	37.15	-72.75	5338	165	191	050133	204301	1035	12
S10	0	1		17	05	45	36.84	-72.75	5338	165	191	050407	219601	681	12
	1	0	TPS	17	08	40	36.58	-72.75	5338						
	0	0	TEMP				36.54	-72.75	5338						
A04	0	2		17	10	26	36.55	-72.87	5338	145	275	050940	252101		1
S11	1	0		17	11	56	36.56	-73.03	5338	145	275				
	0	1		17	13	05	36.57	-73.14	5338	145	275	051128	261901	541	12
A05	0	2		17	16	16	36.59	-73.50	5338	145	275	051531	285401		1
S12	0	1		17	18	57	36.60	-73.70	5338	145	269	051714	295101	846	12
	1	0		17	19	52	36.60	-73.79	5338	145	269				
A06	0	2		17	23	00	36.60	-74.10	5338	145	269	052217	324501		1
S13	0	1		17	24	52	36.59	-74.28	5338	145	269	052315	329601	751	12
S14	0	1	CERC	17	29	55	36.58	-74.78	5338	145	269	052818	359901	375	12
	1	0	CERC	17	30	28	36.58	-74.83	5338	145	269				
S15	0	1	CERC	17	34	38	36.58	-74.83	5338	173	355	053301	389101	1082	12
A07	0	2	CERC	17	37	20	36.58	-74.83	5338	150	267	053633	408701		1
	1	0		17	38	38	36.64	-74.91	5338	150	267				
S16	0	1		17	42	46	36.59	-75.37	5338	150	267	054109	435601	1084	12
	1	0	TPW	17	43	46	36.58	-75.47	5338						
A08	0	2		17	45	00	36.58	-75.47	5338	174	351	054418	452601		1
S17	0	1		17	48	44	37.03	-75.42	5338	174	351	054705	468601	383	12
	1	0		17	50	24	37.18	-75.41	5338	174	351				
S18	1	1		17	53	30	37.48	-75.40	5338	174	351	055151	497201	709	12

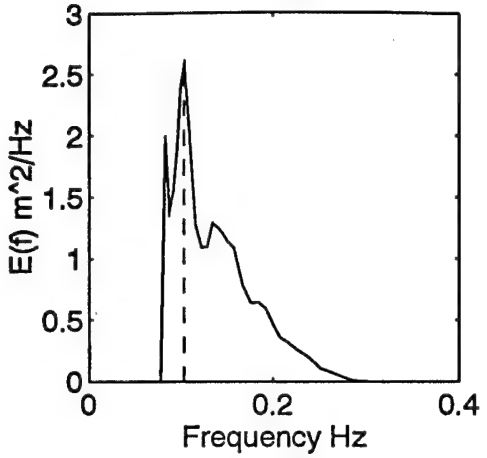
NOTES: (1) MODE '3' IS X-TRACK SPEC MODE DATA FOR CAL AND AVG POWER COMP; PC-TIC TIME HERE IS LST-12 HOURS. (2) S09 MAY HAVE HIGH 'INTERFERENCE' TYPE NOISE LEVEL (3) S10 IS OVER THE FRENCH MERLIN AT 11 KFT. (4) FILES S01-03 AND S06 RERUN WITH NEW PC-TIC TIMES ON 1/28/93 (TIMES HERE LISTED) TO AGREE WITH FILE START TIMES ('ACCURATE TIMES'). (5) RUNS FOR S03 AND S15 BOMBED W/ 'alloc br failure.'

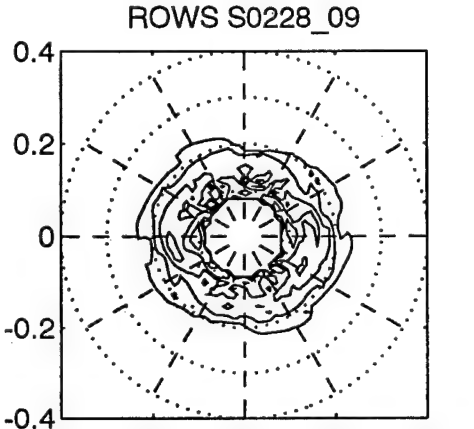

ROWS S0228_01
Hs / Tp = 2.15m / 10.90s
ROWS W = 10.90; md/pd = 239/235
E(f) m^2/Hz
Frequency Hz
ROWS S0228_02
Hs / Tp = 2.16m / 10.92s
ROWS W = 10.86; md/pd = 242/243
E(f) m^2/Hz
Frequency Hz
ROWS S0228_04
Hs / Tp = 2.17m / 10.86s
ROWS W = 10.86; md/pd = 232/228
E(f) m^2/Hz
Frequency Hz


ROWS S0228_05
Hs / Tp = 2.14m / 12.106s
ROWS W = 9.85; md/pd = 219/227
E(f) m^2/Hz
Frequency Hz
ROWS S0228_06
Hs / Tp = 2.15m / 10.89s
ROWS W = 9.82; md/pd = 232/237
E(f) m^2/Hz
Frequency Hz
ROWS S0228_07
Hs / Tp = 2.16m / 9.78s
ROWS W = 9.81; md/pd = 235/227
E(f) m^2/Hz
Frequency Hz

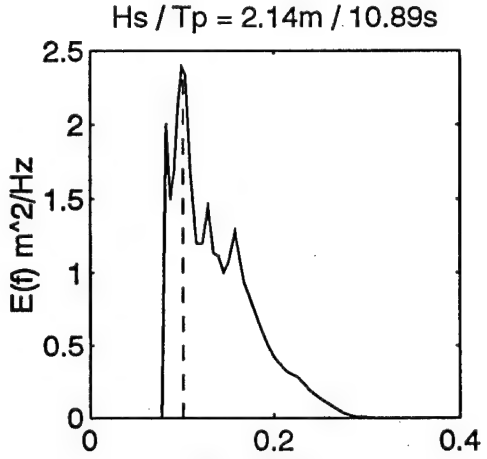


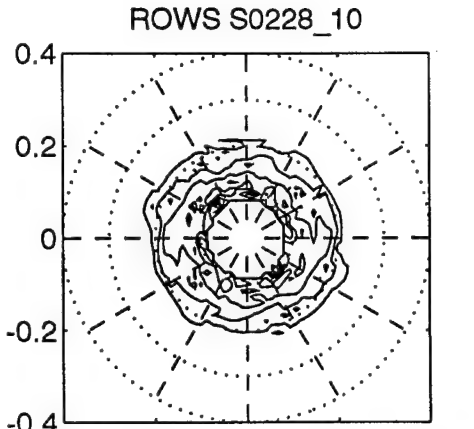
ROWS W = 8.76; md/pd = 232/237



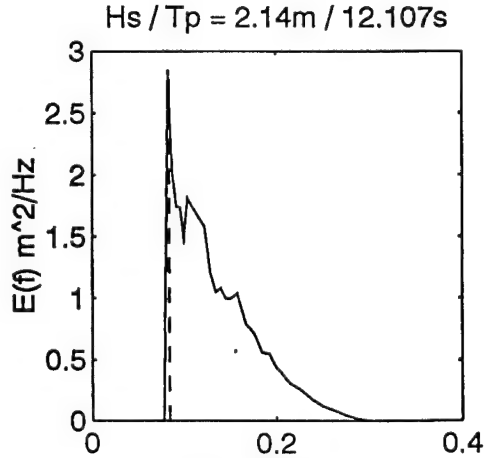


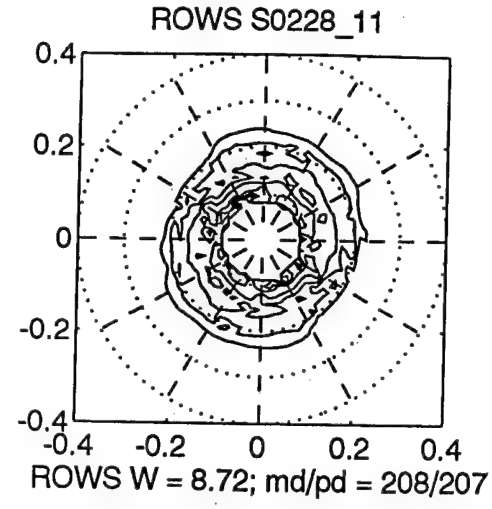
ROWS W = 9.77; md/pd = 265/263

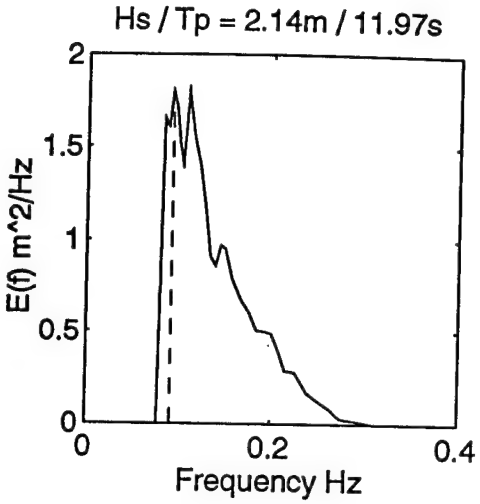


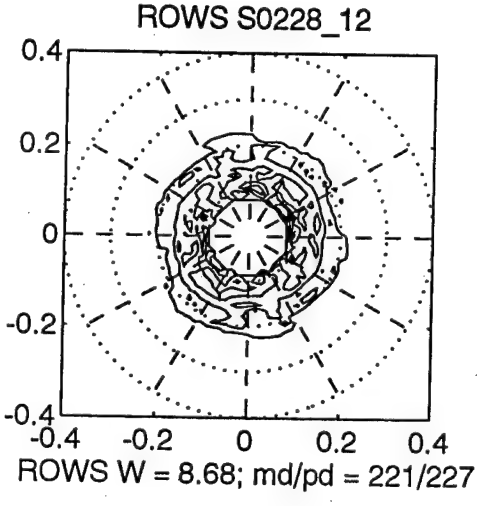


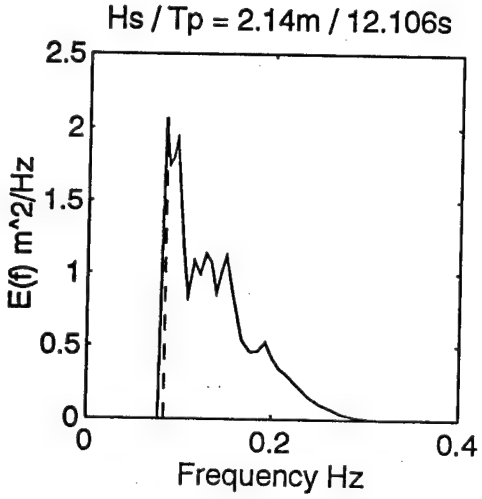
ROWS W = 9.77; md/pd = 243/243

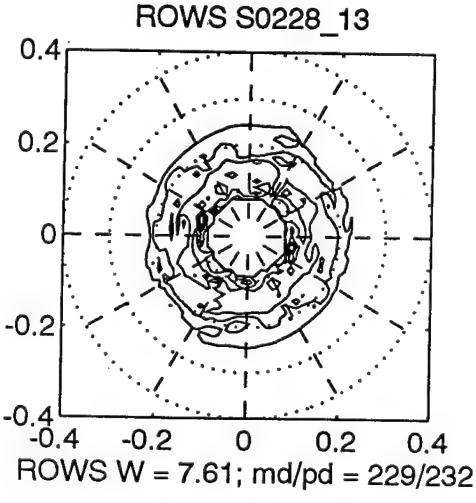


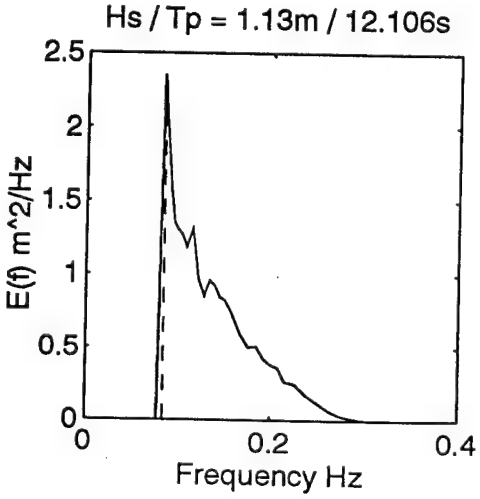

ROWS S0228_11
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 8.72; md/pd = 208/207

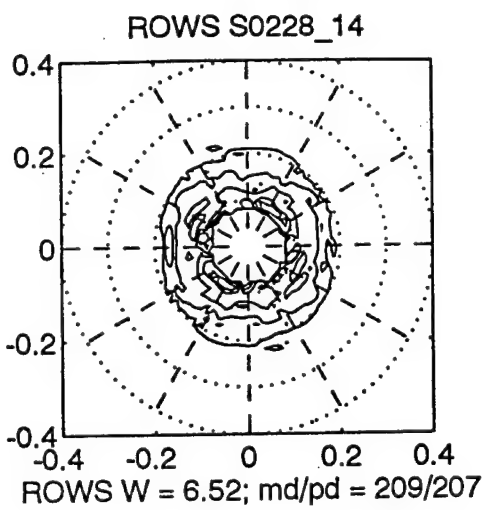

Hs / Tp = 2.14m / 11.97s
E(f) m^2/Hz
2
1.5
1
0.5
0
0 0.2 0.4
Frequency Hz

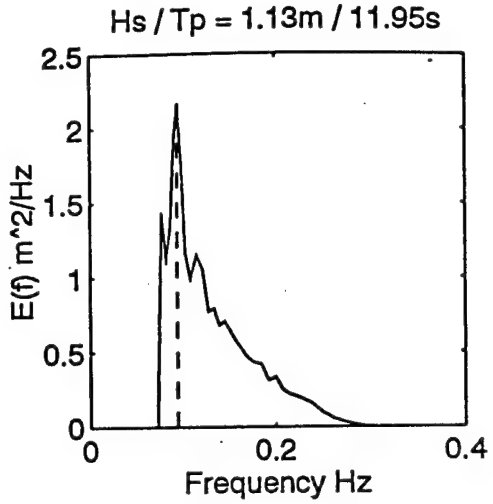

ROWS S0228_12
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 8.68; md/pd = 221/227

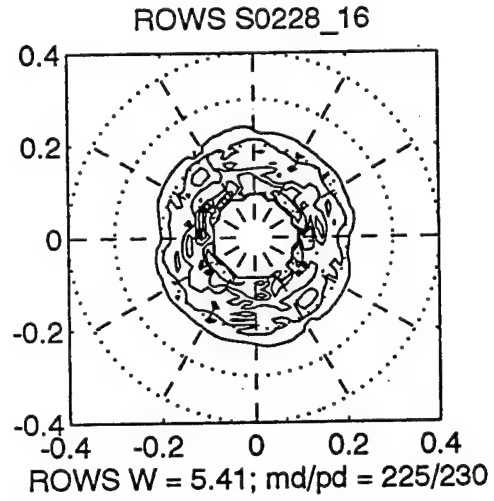

Hs / Tp = 2.14m / 12.106s
E(f) m^2/Hz
2.5
2
1.5
1
0.5
0
0 0.2 0.4
Frequency Hz

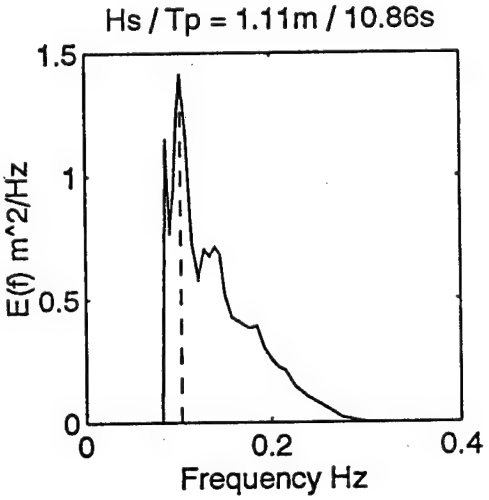

ROWS S0228_13
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 7.61; md/pd = 229/232

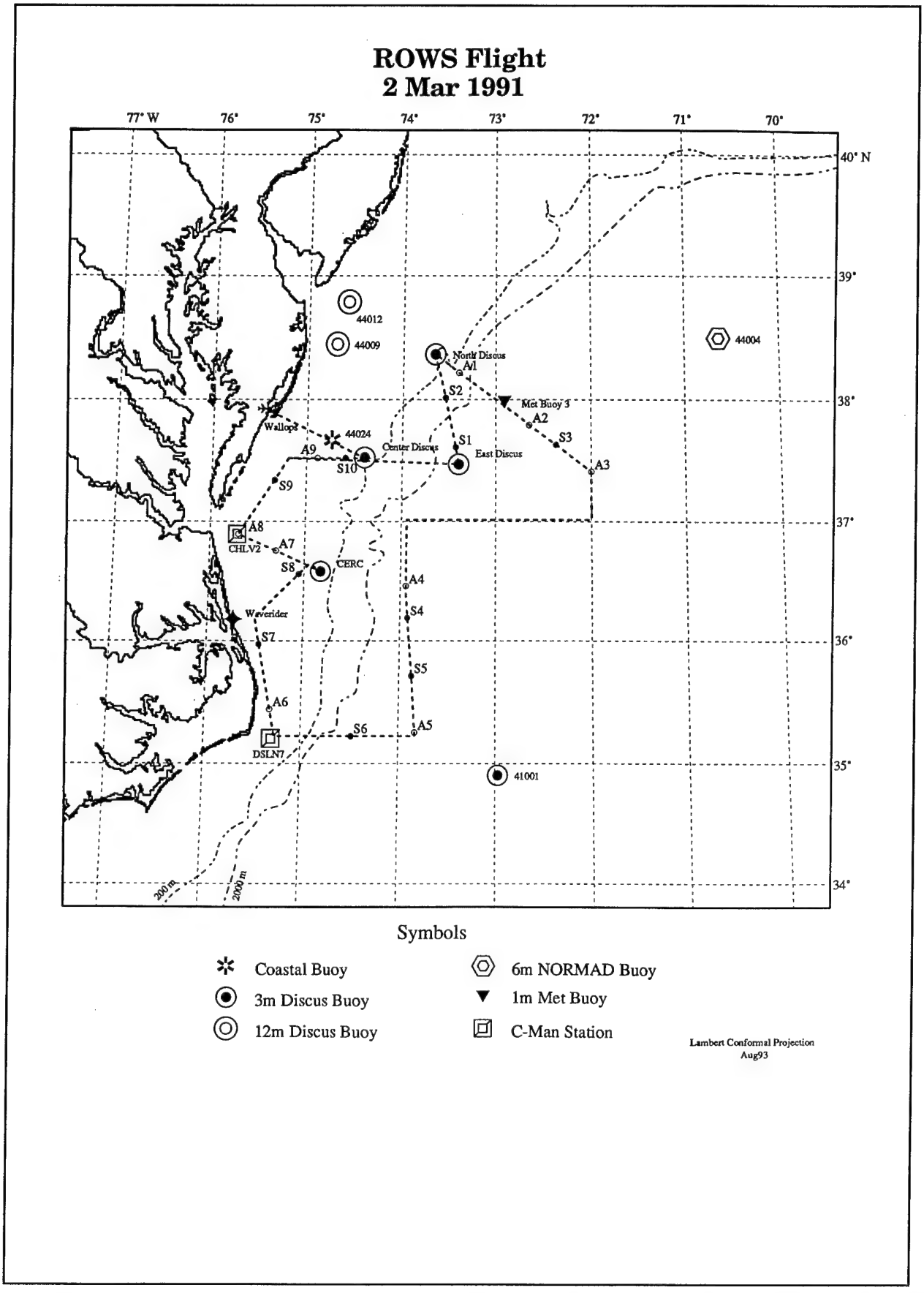

Hs / Tp = 1.13m / 12.106s
E(f) m^2/Hz
2.5
2
1.5
1
0.5
0
0 0.2 0.4
Frequency Hz


ROWS S0228_14
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 6.52; md/pd = 209/207


Hs / Tp = 1.13m / 11.95s
2.5
2
1.5
1
0.5
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz


ROWS S0228_16
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 5.41; md/pd = 225/230

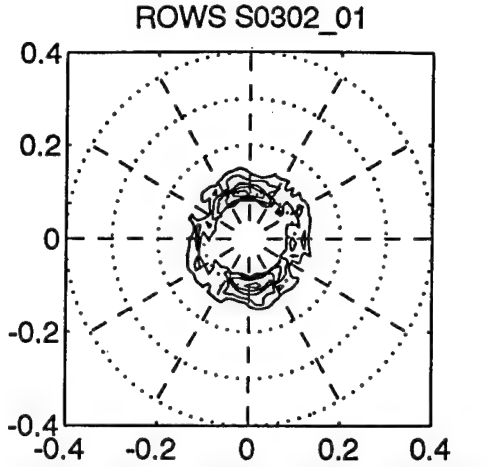

Hs / Tp = 1.11m / 10.86s
1.5
1
0.5
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz


ROWS Flight
2 Mar 1991
77° W
76°
75°
74°
73°
72°
71°
70°
40° N
39°
38°
37°
36°
35°
34°
44012
44009
44004
North Discus
A1
S2
Met Buoy 3
A2
S3
A3
Wallops
44024
A9
S10
Center Discus
S1
East Discus
S9
A8
CHLV2
A7
S8
CERC
A4
S4
Waverider
S7
S5
A6
S6
A5
DSLN7
41001
200 m
2000 m
Symbols
Coastal Buoy
3m Discus Buoy
12m Discus Buoy
6m NORMAD Buoy
1m Met Buoy
C-Man Station
Lambert Conformal Projection
Aug93

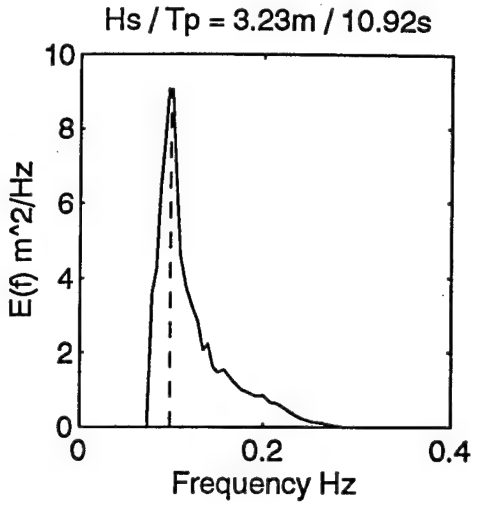
ROWS SWADE FLIGHT NAVIGATION AND FILE DATA
MAR 02, 1991

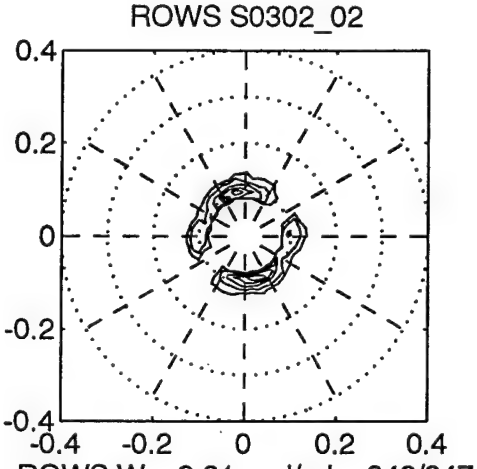
TAPE1/1 FILE	POS FIX	ROWS MODE	BUOY/ WP	EST HH	MM	SS	LAT	LON	ALT	SPD M/S	HDG TRU	PC-TIC START	REC # START	0 DEG DELTA	LEN MB
	1	0	WFF				37.94	-75.47	0						
	1	0	DIS-C	15	48	25	37.53	-74.39							
	0	0	TEMP1				37.53	-75.19	8235						
	1	0	DIS-E	16	00	16	37.48	-73.40	8235						
S01	1	1		16	03	03	37.62	-73.43	8235	206	336	155811	45601	989	12
S02	0	1		16	06	14	38.02	-73.54	8235	206	336	160122	64701	822	12
	1	0	DIS-N	16	08	14	38.37	-73.66							
A01	0	2		16	12	00	38.22	-73.40	7930	165	143	160900	100001		1
	1	0		16	19	14	37.86	-72.74	7930	165	143				
A02	0	2		16	20	05	37.80	-72.65	7930	165	143	161715	146001		1
S03	0	1		16	22	57	37.64	-72.37	7930	165	143	161837	152501	123	18
A03	1	2	TPN	16	26	40	37.42	-72.00	7930	165	143	162336	180401		1
	0	0	TEMP2				37.02	-72.00							
	1	0		16	37	09	37.02	-72.59							
	0	0	TEMP3				37.02	-73.94	10553						
A04	0	2		16	56	26	36.46	-73.94	10553	175	181	165319	229701		1
	1	0		16	57	08	36.40	-73.94	10553	175	181				
S04	0	1		17	00	00	36.19	-73.92	10553	175	181	165609	245101	404	12
S05	0	1		17	04	30	35.71	-73.87	10553	175	181	170039	269001	444	12
A05	0	2		17	07	08	35.25	-73.83	10553	175	181	170357	289701		1
	1	0	TPS	17	07	30	35.22	-73.83	10553						
S06	1	1		17	16	30	35.22	-74.48	10553	189	267	171147	335301	304	18
	1	0	TPW				35.22	-75.27	7015						
A06	0	2		17	26	36	35.44	-75.32	7015	185	350	172322	356401		1
	1	0		17	28	20	35.64	-75.37	7015	185	350				
S07	0	1		17	32	40	35.97	-75.45	7015	185	350	172714	377800	752	12
	1	0	TPW'	17	33	50	36.19	-75.50	7015						
S08	1	1		17	38	15	36.56	-75.06	7015	205	070	173353	417601	857	12
	0	0	TEMP4				36.66	-74.96							
	1	0	CERC	17	45	10	36.58	-74.83	9608						
A07	0	2		17	49	46	36.76	-75.30	9608			174618	433101		1
A08	1	2	CLT	17	53	20	36.90	-75.70	9608			174944	450601		1
S09	1	1		17	59	34	37.35	-75.33	10675	221	055	175506	457501	500	12
	1	0	TEMP1				37.53	-75.19							
A09	0	2		18	03	20	37.53	-74.89	10065	195	101	175940	473001		1
S10	0	1		18	05	23	37.53	-74.59	10065	195	101	180013	475001	237	18
	1	0		18	07	06	37.53	-74.39	10065	195	101				

NOTES: (1) S09 BOMBED,'nadir return < 25 bins'. (2) S07 RERUN W/ NEW PC TIC TIME. (3) LAT/LON CORRECTION FOR TIMING PROBLEMS (PC TIC VS LOG TIME) WITH FILES S01 (SECTOR 1 START TIME 160058) AND S02 (SECTOR 1 START TIME 160407).

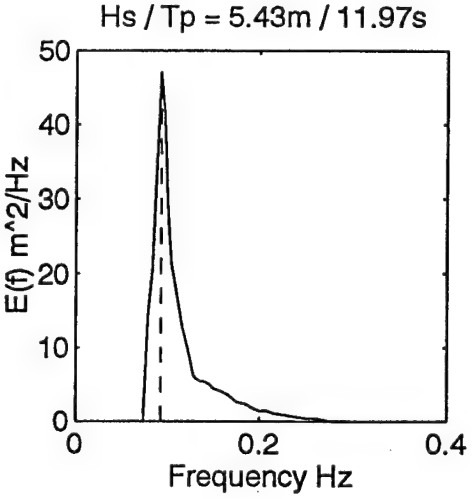


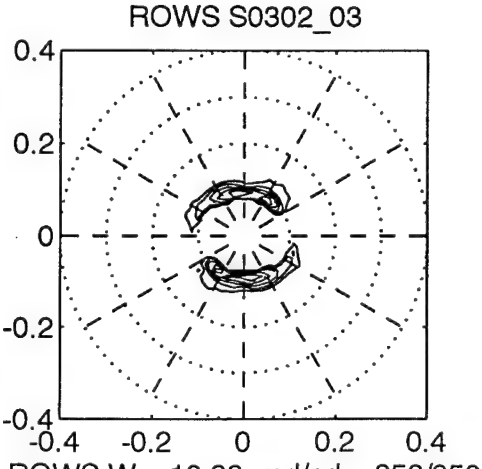
ROWS W = 10.86; md/pd = 351/350



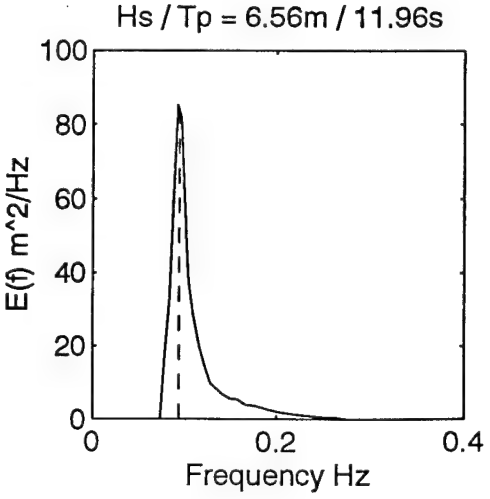


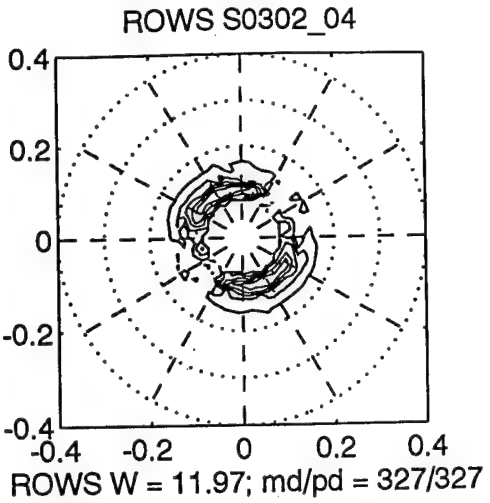
ROWS W = 9.81; md/pd = 342/347

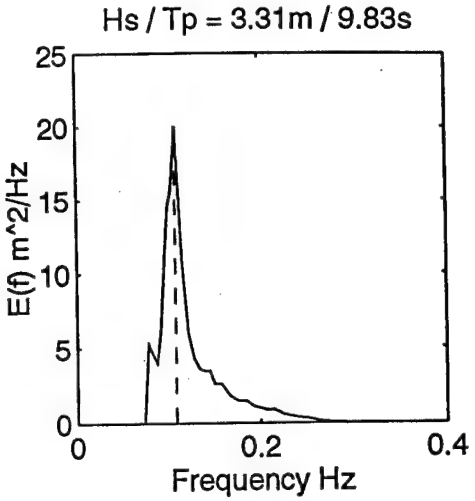


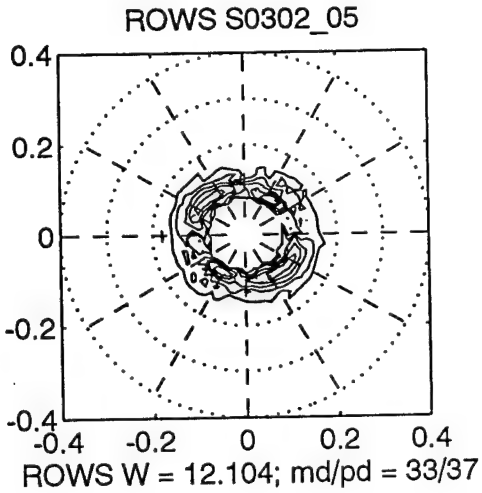


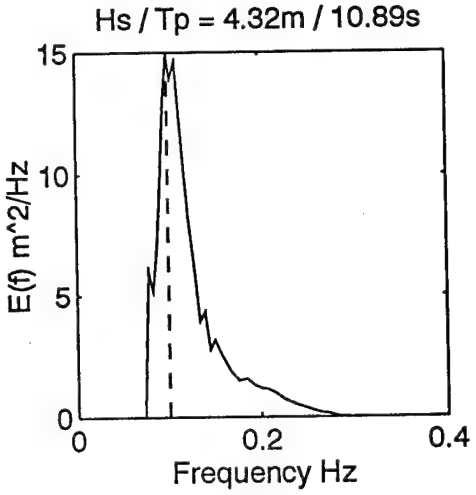
ROWS W = 10.93; md/pd = 358/350

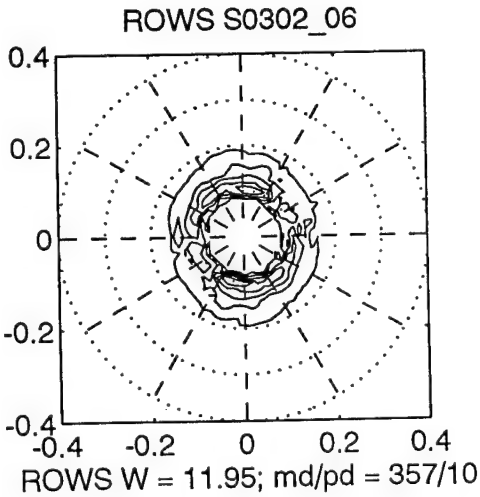


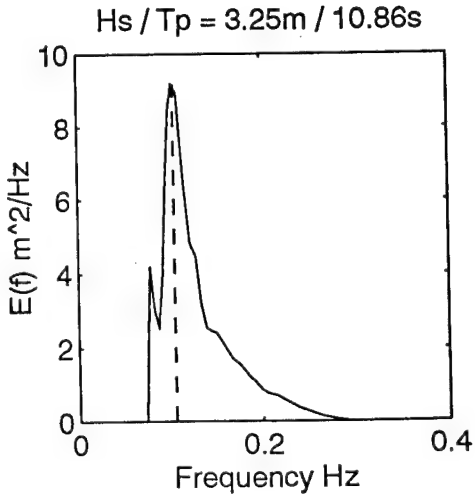

ROWS S0302_04
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 11.97; md/pd = 327/327

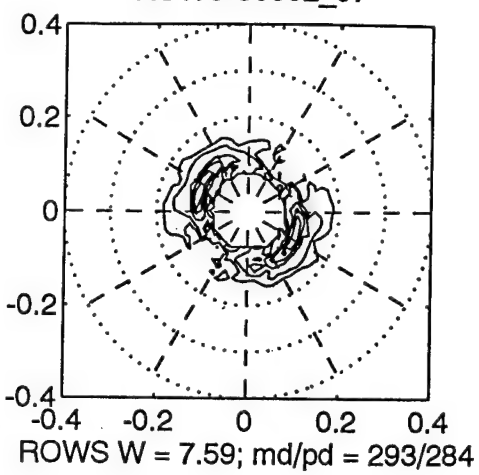

Hs / Tp = 3.31m / 9.83s
25
20
15
10
5
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz

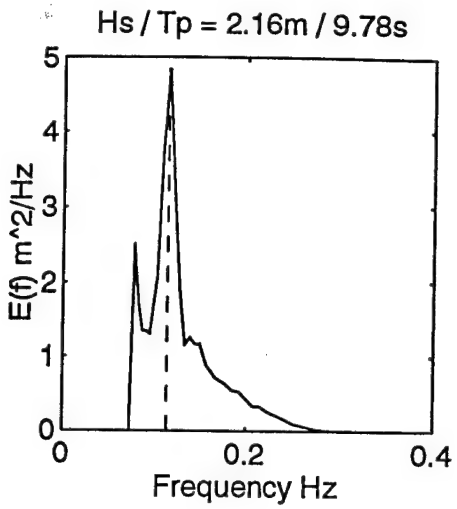

ROWS S0302_05
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 12.104; md/pd = 33/37

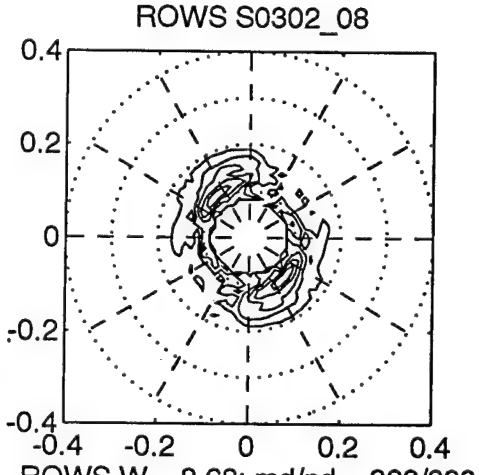

Hs / Tp = 4.32m / 10.89s
15
10
5
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz

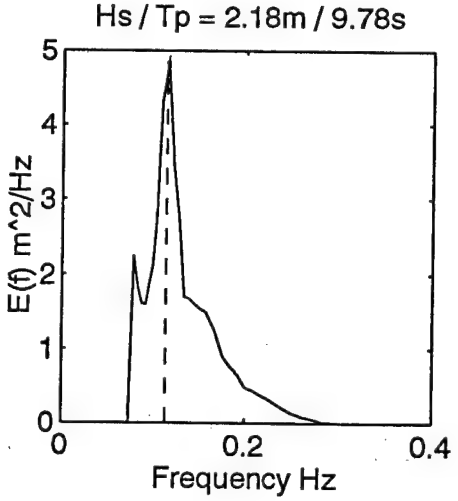

ROWS S0302_06
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 11.95; md/pd = 357/10

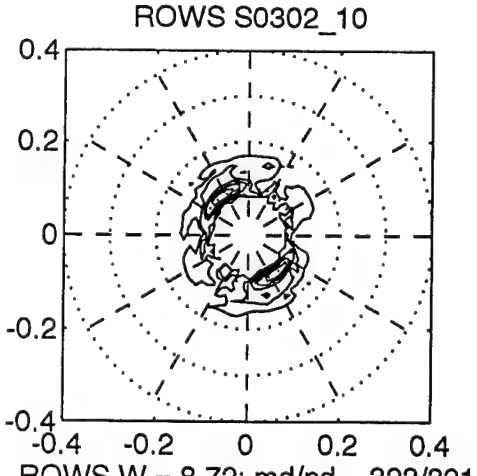

Hs / Tp = 3.25m / 10.86s
10
8
6
4
2
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz

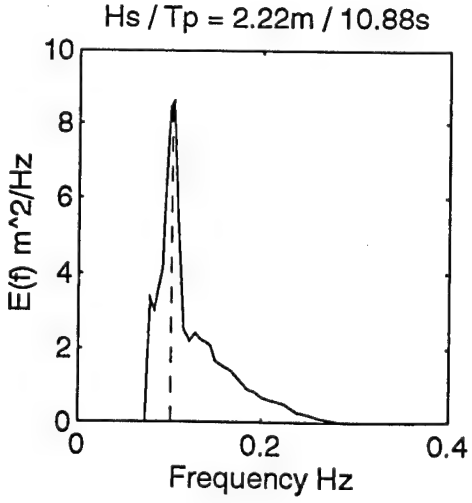

ROWS S0302_07
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 7.59; md/pd = 293/284

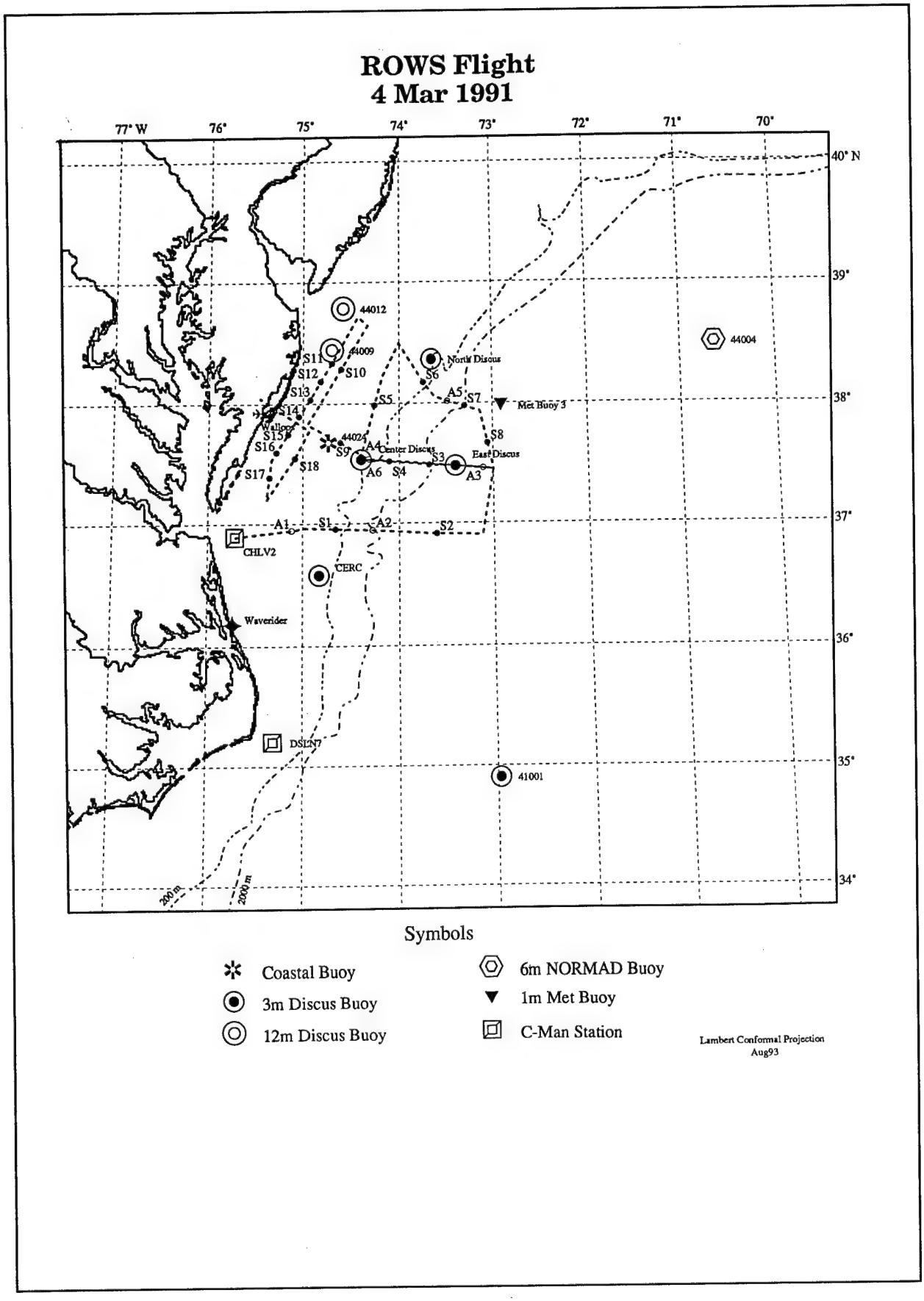

Hs / Tp = 2.16m / 9.78s
E(f) m^2/Hz
5
4
3
2
1
0
0 0.2 0.4
Frequency Hz


ROWS S0302_08
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 8.68; md/pd = 323/320


Hs / Tp = 2.18m / 9.78s
E(f) m^2/Hz
5
4
3
2
1
0
0 0.2 0.4
Frequency Hz


ROWS S0302_10
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 8.72; md/pd = 323/321

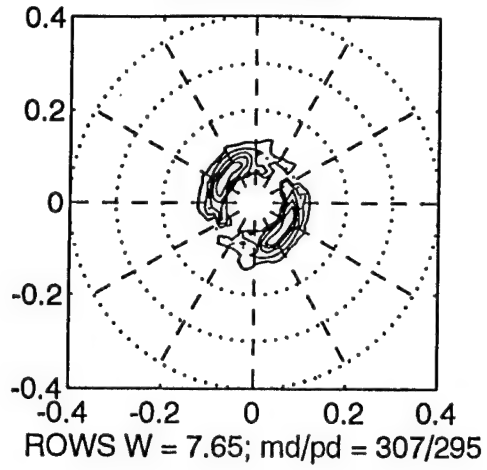

Hs / Tp = 2.22m / 10.88s
E(f) m^2/Hz
10
8
6
4
2
0
0 0.2 0.4
Frequency Hz

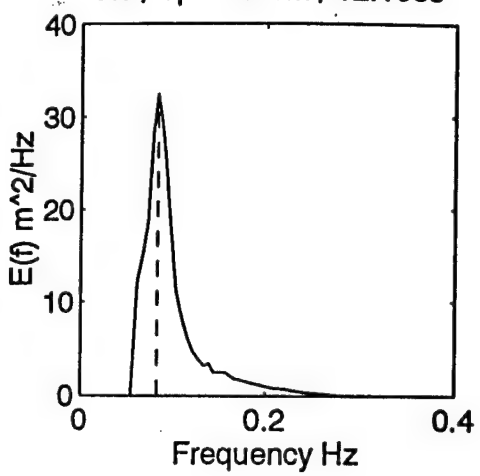

ROWS Flight
4 Mar 1991
77° W
76°
75°
74°
73°
72°
71°
70°
40° N
39°
38°
37°
36°
35°
34°
44012
44009
44004
44024
41001
CHLV2
CERC
DSLN7
Waverider
North Discus
Center Discus
East Discus
Met Buoy 3
S1
S2
S3
S4
S5
S6
S7
S8
S9
S10
S11
S12
S13
S14
S15
S16
S17
S18
A1
A2
A3
A4
A5
A6
Wallops
200 m
2000 m
Symbols
Coastal Buoy
3m Discus Buoy
12m Discus Buoy
6m NORMAD Buoy
1m Met Buoy
C-Man Station
Lambert Conformal Projection
Aug93

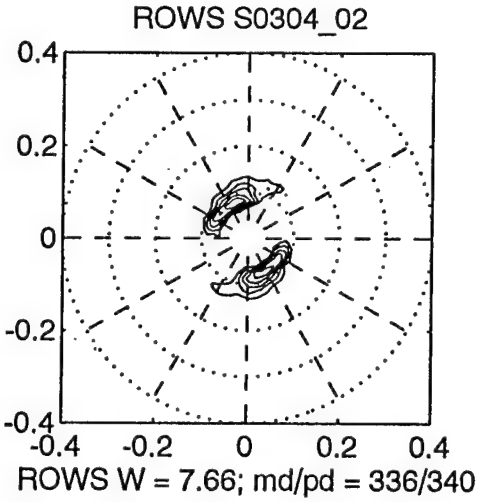
ROWS SWADE FLIGHT NAVIGATION AND FILE DATA
MAR 04, 1991

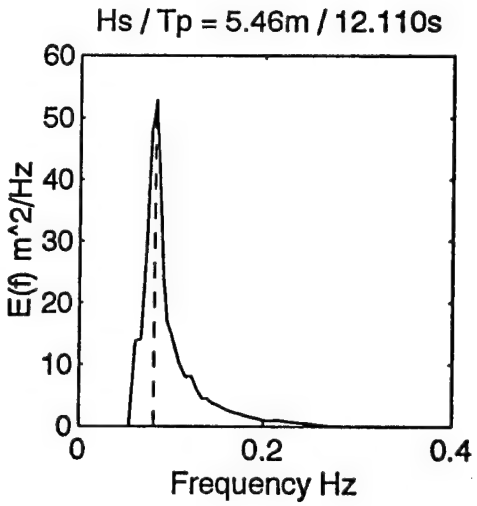
TAPE1/1 FILE	POS FIX	ROWS MODE	BUOY/ WP	EST HH	MM	SS	LAT	LON	ALT	SPD M/S	HDG TRU	PC-TIC START	REC # START	0 DEG DELTA	LEN MI
	1	0	CLT				36.90	-75.70	7625						
A01	0	2		16	34	26	36.95	-75.12	7625			163312	16901		1
	1	0		16	35	26	36.97	-74.99	7625	205	103				
S01	0	1		16	38	00	36.96	-74.66	7625	205	103	163506	26201	638	18
A02	0	2		16	41	22	36.95	-74.27	7625	205	103	163959	54301		1
	1	0		16	46	14	36.92	-73.66	7625	205	103				
S02	0	1		16	46	40	36.92	-73.60	7625	205	103	164335	66601	426	18
	1	0	TPS	16	49	35	36.91	-73.12	7625						
	1	0	TP1				37.45	-73.00	8235						
A03	0	2		17	04	05	37.46	-73.11	8235			170235	128201		1
	1	0	DIS-E	17	06	45	37.48	-73.40	8235	161	256				
S03	0	1		17	07	55	37.49	-73.68	8235	161	256	170529	133001	260	12
S04	0	1		17	11	05	37.52	-74.10	8235	161	256	170829	150901	330	12
	1	0	DIS-C	17	13	05	37.54	-74.39	8235						
A04	0	2		17	16	21	37.56	-74.39	8235	262	000	171441	172501		1
	1	0		17	18	30	37.92	-74.27	8235	262	000				
S05	0	1		17	19	00	37.99	-74.25	8235	262	000	171607	180101	879	12
	1	0		17	20	30	38.23	-74.17	8235	262	000				
	1	0	TPN				38.50	-74.00	8235						
S06	0	1		17	24	00	38.18	-73.74	8235	163	157	172110	195101	1009	12
	1	0		17	25	02	38.13	-73.69	8235	163	157				
	0	0	TEMP	17	25	26	38.06	-73.62	8540						
A05	0	2		17	27	18	38.02	-73.48	8540	177	128	172529	211701		1
S07	0	1		17	29	00	37.98	-73.30	8540	177	128	172602	213401	1106	12
	1	0		17	29	36	37.96	-73.24	8540	177	128				
	0	0	TEMP	17	30	20	37.94	-73.14	8540						
	1	0		17	33	06	37.74	-73.08	8540	136	177				
S08	0	1		17	34	06	37.67	-73.06	8540	136	177	173034	231801	259	18
	1	0	TP1				37.45	-73.00	8540						
	1	0	DIS-E	17	40	21	37.48	-73.40	8540						
A06	0	2	DIS-C	17	48	00	37.54	-74.31	8540	171	251	174553	289501		1
S09	0	1		17	52	50	37.68	-74.61	8540	201	278	174839	318001	815	12
	1	0	TP3	17	54	03	37.83	-74.96	8540						
S10	1	1		17	59	03	38.29	-74.60	8540	263	038	175603	337701	811	10
	1	0	TP4				38.65	-74.32	8540						
	0	0	TEMP				38.72	-74.42	8540						
S11	1	1		18	05	47	38.34	-74.70	8540	132	207	180224	355901	153	12
S12	0	1		18	08	13	38.19	-74.82	8540	132	207	180450	370461	571	12
S13	0	1		18	10	39	38.04	-74.93	8540	132	208	180716	385021	985	12
S14	0	1		18	13	05	37.90	-75.05	8540	132	209	180942	399581	403	12
S15	0	1		18	15	31	37.75	-75.16	8540	132	210	181208	414141	788	12
S16	1	1		18	17	55	37.60	-75.28	8540	123	210	181434	428701	188	12
	0	0	TEMP				37.53	-75.33	8540						
S17	1	1		18	21	10	37.39	-75.35	8540	143	179	181752	448501	358	10
	0	0					37.20	-75.38	8540						
S18	1	1		18	25	45	37.55	-75.09	8540	258	017	182226	463501	248	10
	0	0	TEMP				37.78	-74.94							
	0	0	SNOW				38.05	-75.45							

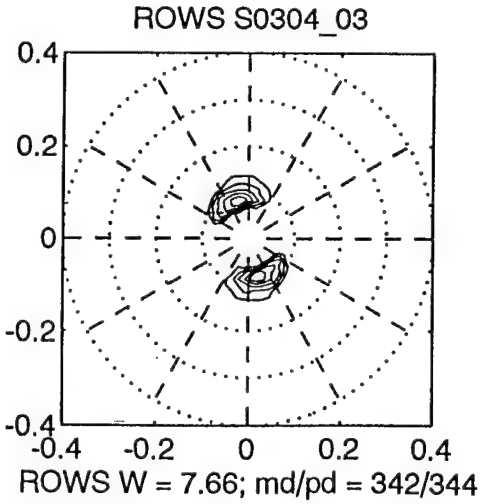
NOTES: (1) S17 BOMBED FOR 'alloc br failure'. (2) S09 TIMING--LAT/LON CORRECTED. (3) A04 BOMBED, 'nadir fell into noise calc window'. (4) A06 BAD, FILE START TIME ERROR.

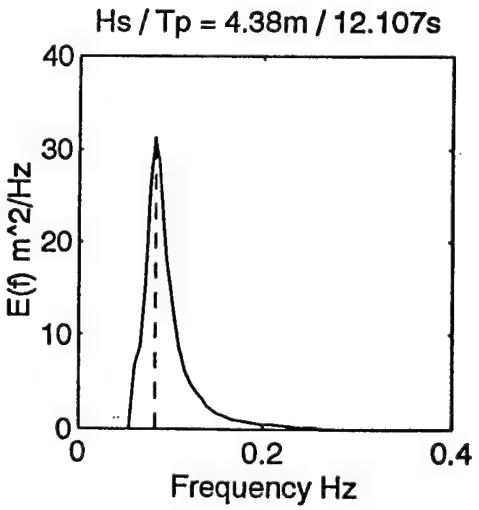

ROWS S0304_01
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 7.65; md/pd = 307/295

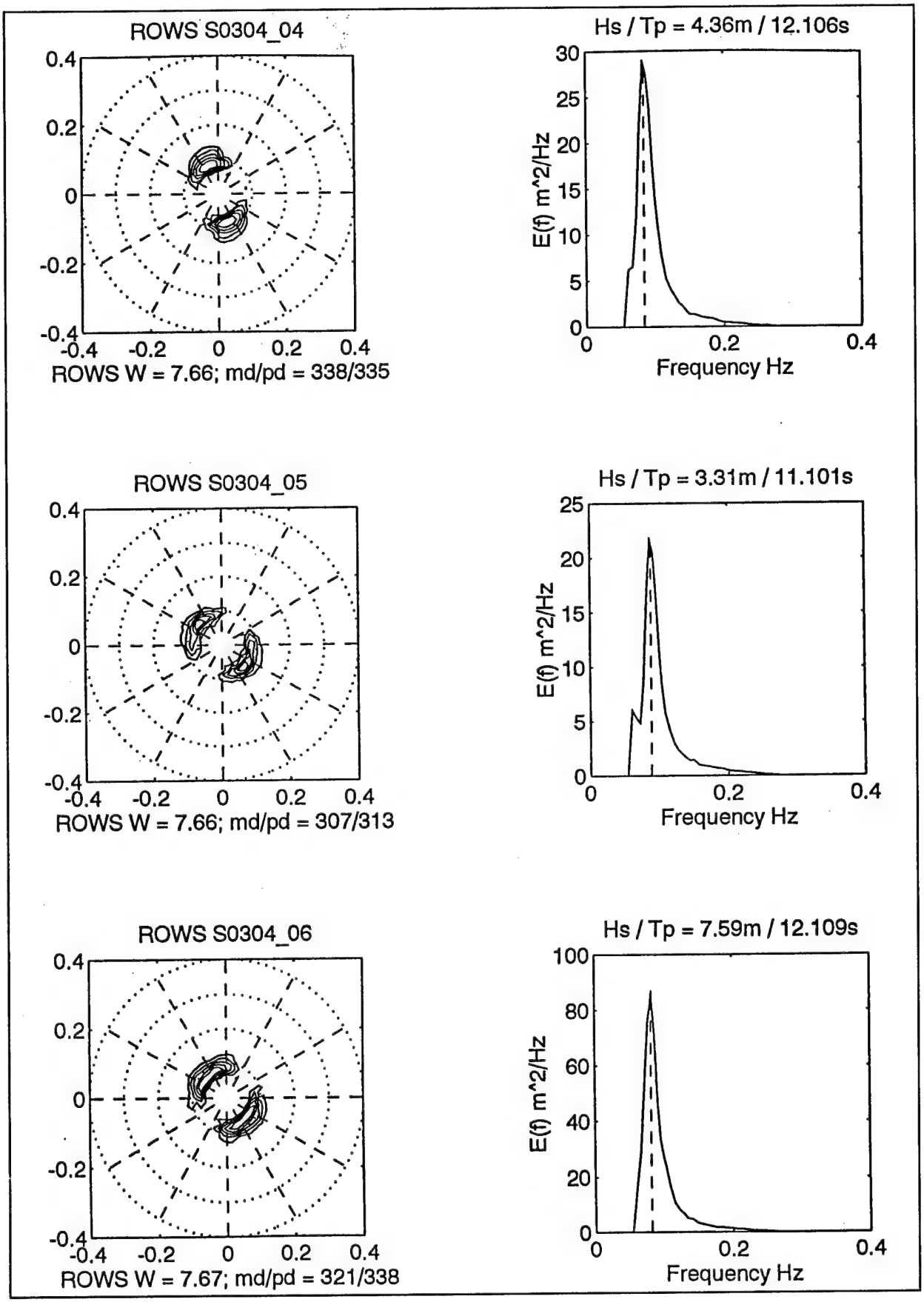

Hs / Tp = 5.41m / 12.108s
40
30
20
10
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz

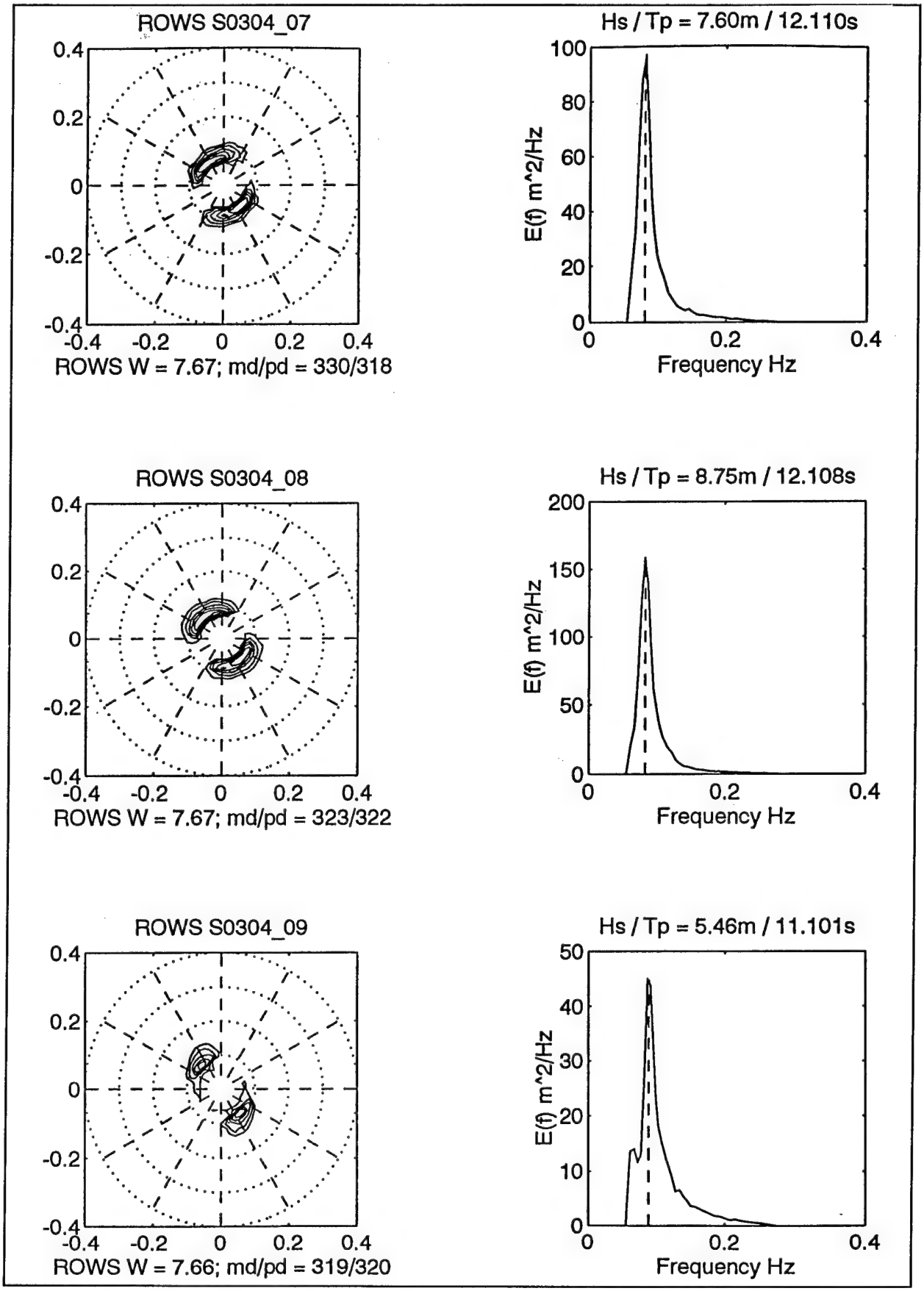

ROWS S0304_02
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 7.66; md/pd = 336/340

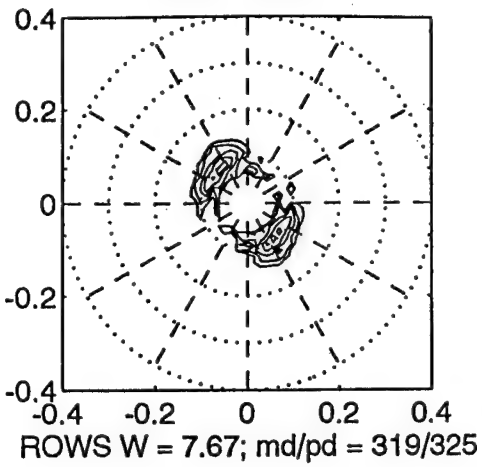

Hs / Tp = 5.46m / 12.110s
60
50
40
30
20
10
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz

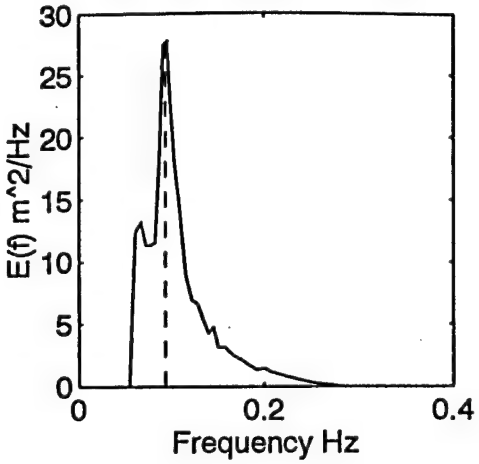

ROWS S0304_03
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 7.66; md/pd = 342/344

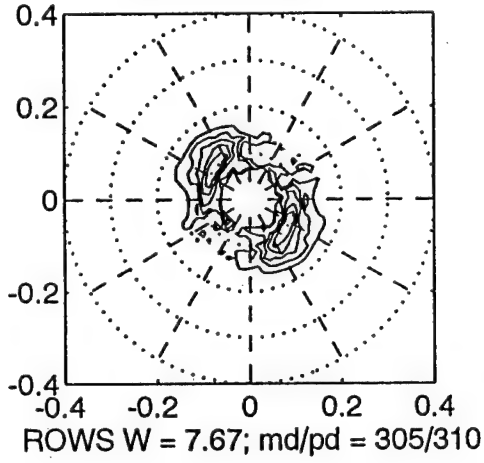

Hs / Tp = 4.38m / 12.107s
40
30
20
10
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz

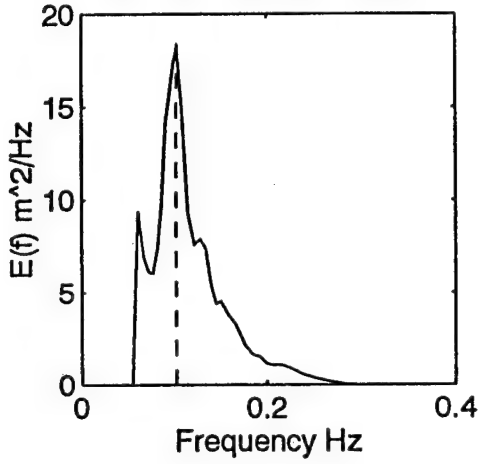

ROWS S0304_04
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 7.66; md/pd = 338/335
Hs / Tp = 4.36m / 12.106s
30
25
20
15
10
5
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz
ROWS S0304_05
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 7.66; md/pd = 307/313
Hs / Tp = 3.31m / 11.101s
25
20
15
10
5
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz
ROWS S0304_06
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 7.67; md/pd = 321/338
Hs / Tp = 7.59m / 12.109s
100
80
60
40
20
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz

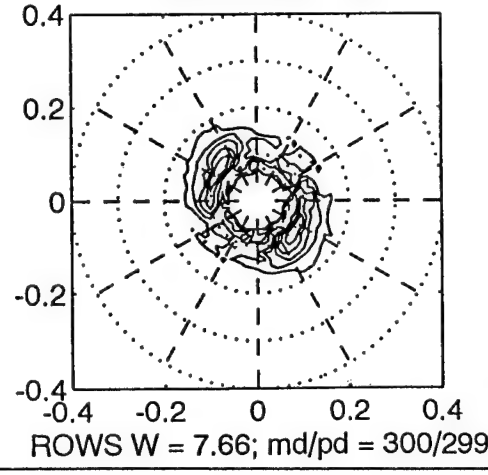

ROWS S0304_07
Hs / Tp = 7.60m / 12.110s
ROWS W = 7.67; md/pd = 330/318
E(f) m^2/Hz
Frequency Hz
ROWS S0304_08
Hs / Tp = 8.75m / 12.108s
ROWS W = 7.67; md/pd = 323/322
E(f) m^2/Hz
Frequency Hz
ROWS S0304_09
Hs / Tp = 5.46m / 11.101s
ROWS W = 7.66; md/pd = 319/320
E(f) m^2/Hz
Frequency Hz

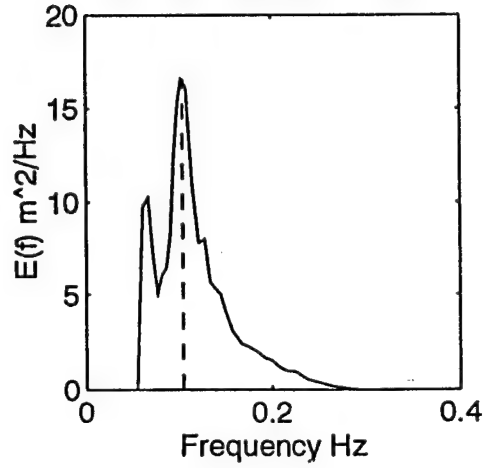

ROWS S0304_10
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 7.67; md/pd = 319/325

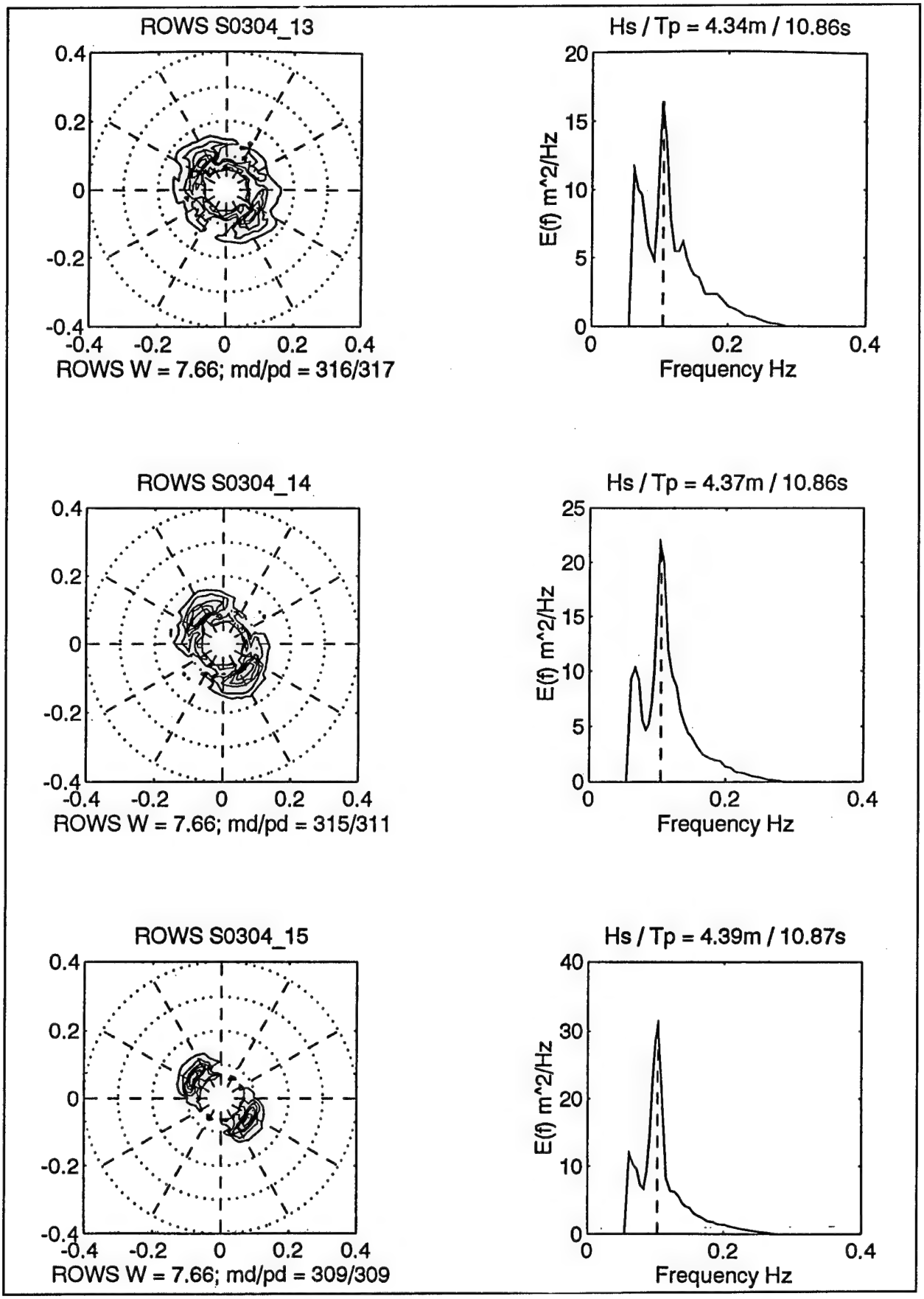

Hs / Tp = 4.40m / 11.95s
30
25
20
15
10
5
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz

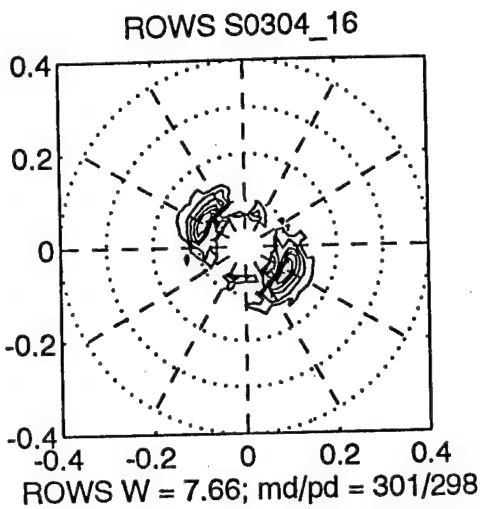

ROWS S0304_11
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 7.67; md/pd = 305/310

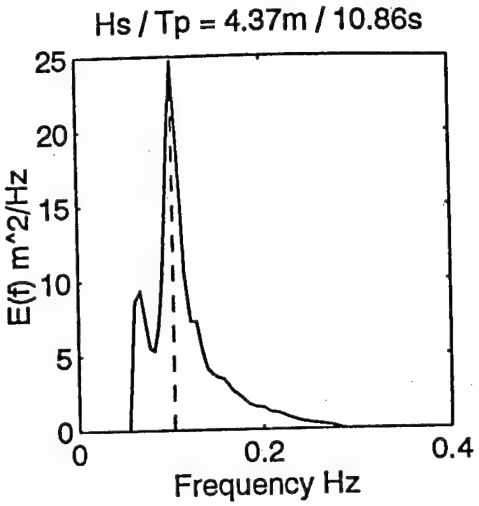

Hs / Tp = 4.37m / 10.87s
20
15
10
5
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz

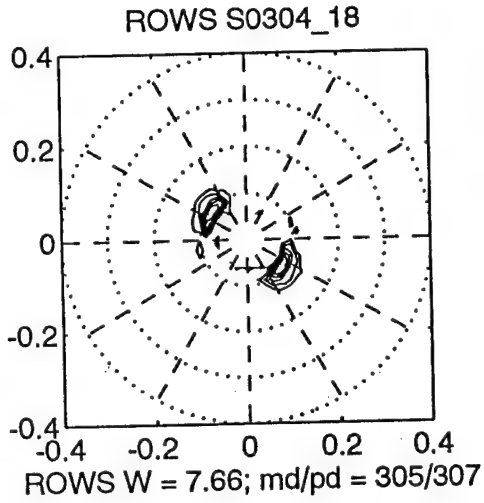

ROWS S0304_12
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 7.66; md/pd = 300/299

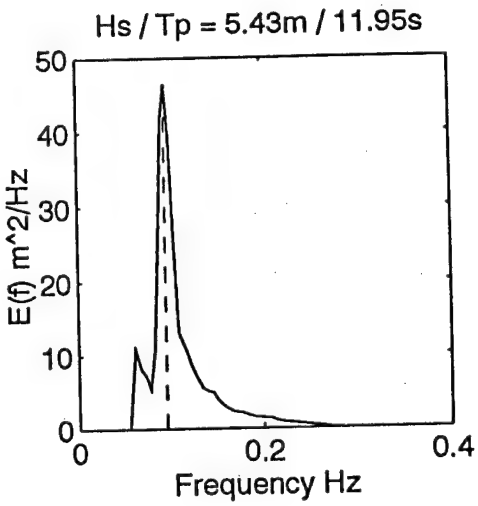

Hs / Tp = 4.36m / 10.86s
20
15
10
5
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz

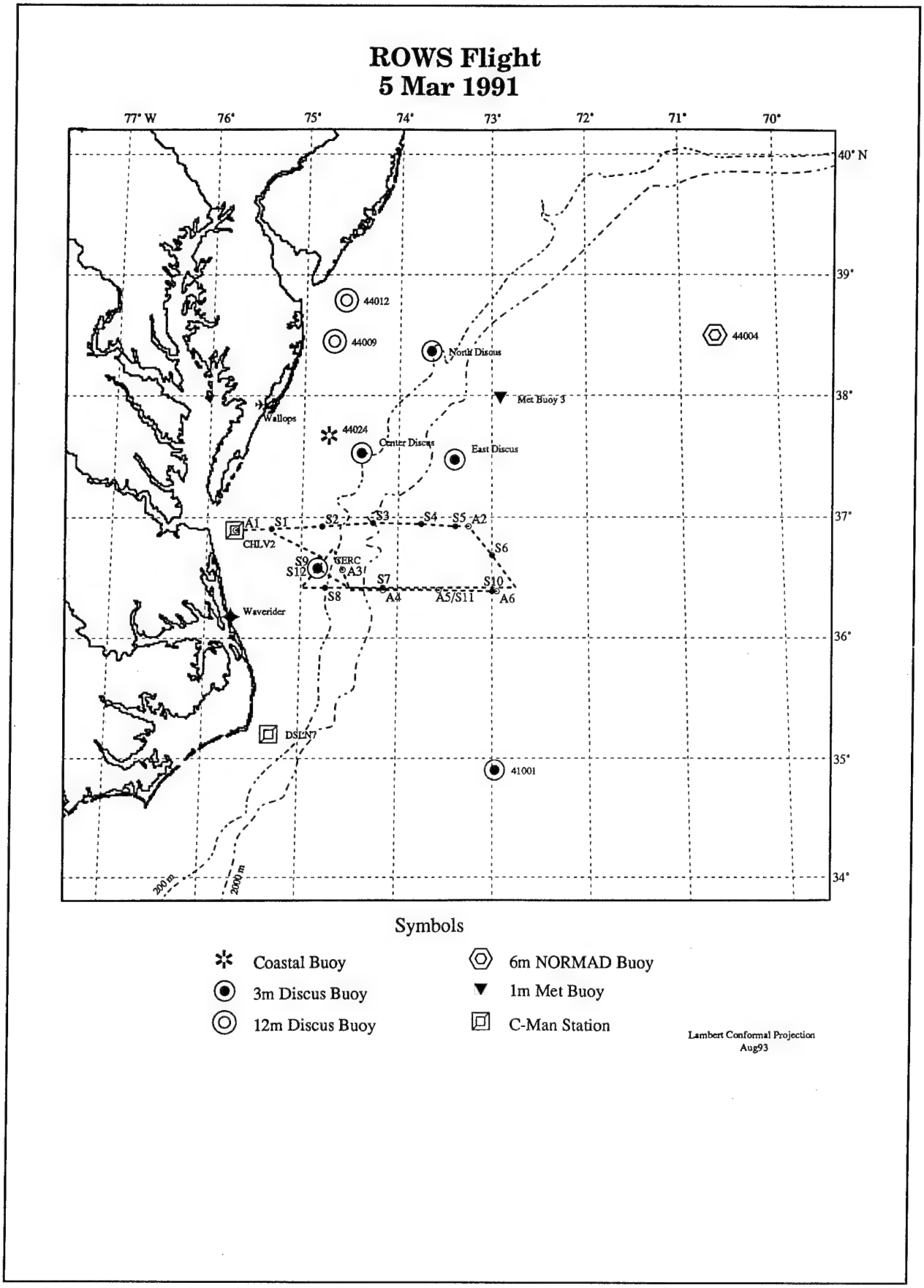

ROWS S0304_13
Hs / Tp = 4.34m / 10.86s
ROWS W = 7.66; md/pd = 316/317
E(f) m^2/Hz
Frequency Hz
ROWS S0304_14
Hs / Tp = 4.37m / 10.86s
ROWS W = 7.66; md/pd = 315/311
E(f) m^2/Hz
Frequency Hz
ROWS S0304_15
Hs / Tp = 4.39m / 10.87s
ROWS W = 7.66; md/pd = 309/309
E(f) m^2/Hz
Frequency Hz


ROWS S0304_16
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 7.66; md/pd = 301/298


Hs / Tp = 4.37m / 10.86s
25
20
15
10
5
0
E(f) m^2/Hz
0
0.2
0.4
Frequency Hz


ROWS S0304_18
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 7.66; md/pd = 305/307

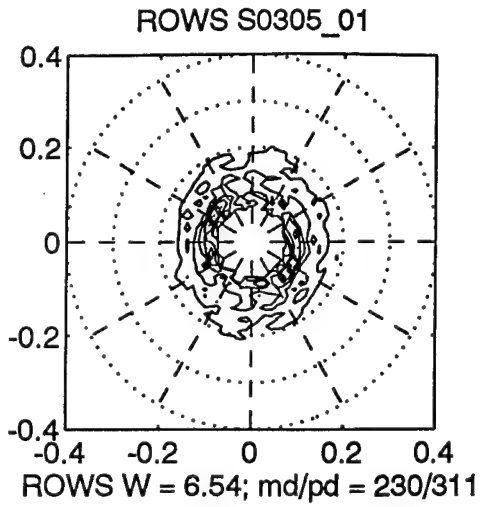

Hs / Tp = 5.43m / 11.95s
50
40
30
20
10
0
E(f) m^2/Hz
0
0.2
0.4
Frequency Hz

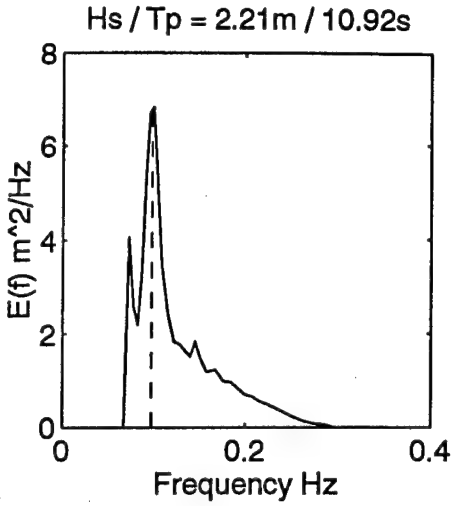

ROWS Flight
5 Mar 1991
77° W
76°
75°
74°
73°
72°
71°
70°
40° N
39°
38°
37°
36°
35°
34°
44012
44009
44004
North Discus
Met Buoy 3
Wallops
44024
Center Discus
East Discus
A1
S1
S2
S3
S4
S5
A2
CHLV2
S6
S9
S12
WERC
A3
S7
S10
S8
A4
A5/S11
A6
Waverider
DSLN7
41001
200 m
2000 m
Symbols
Coastal Buoy
3m Discus Buoy
12m Discus Buoy
6m NORMAD Buoy
1m Met Buoy
C-Man Station
Lambert Conformal Projection
Aug93

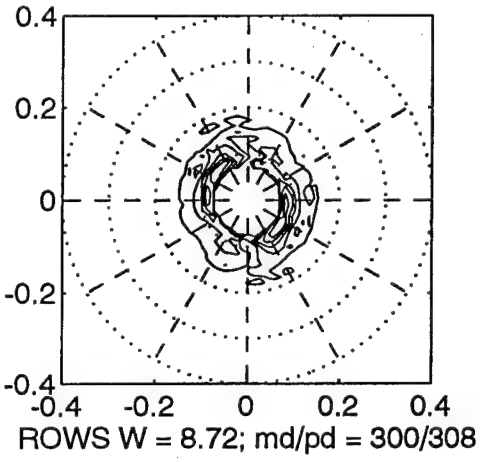
ROWS SWADE FLIGHT NAVIGATION AND FILE DATA
MAR 05, 1991

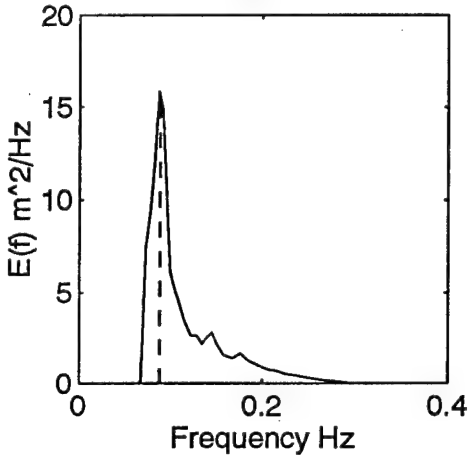
TAPE1/1 FILE	POS FIX	ROWS MODE	BUOY/ WP	EST HH MM SS	LAT	LON	ALT M	SPD M/S	HDG TRU	PC-TIC START	REC # START	0 DEG DELTA	LEN ME
A01	1	2	CLT	12 02 33	36.90	-75.70	7000	183	086	120040	9400		1
S01	1	1		12 05 45	36.91	-75.32	7000	183	086	120220	18900	698	12
S02	0	1		12 10 04	36.93	-74.79	7000	183	086	120639	44800	755	12
S03	1	1		12 14 12	36.96	-74.26	7000	183	092	121047	69600	899	12
S04	0	1		12 17 52	36.95	-73.75	7000	183	092	121427	91500	851	12
S05	0	1		12 20 28	36.93	-73.39	7000	183	092	121803	113000	421	12
	1	0	TPN	12 21 33	36.93	-73.25	9608						
A02	0	2		12 40 18	36.93	-73.25	9608	169	163	123754	123400		1
S06	1	1		12 44 08	36.69	-73.00	9608	169	163	124041	139300	846	12
	1	0	TPS	12 47 23	36.42	-72.75	9608						
S07	0	1		12 59 26	36.42	-74.15	9608	165	255	125554	222100	1042	12
	1	0	TPW	13 02 36	36.42	-74.50	9608	165	255				
S08	0	1		13 04 56	36.42	-74.75	9608	165	255	130103	253000	1095	16
	1	0	TPW'	13 07 15	36.42	-75.00	9608						
S09	1	1	CERC	13 11 42	36.58	-74.83	9608	232	018	130726	275100	351	10
	0	0	TEMP	13 14 00	36.75	-74.67	9608						
A03	1	2		13 17 45	36.57	-74.57	9608	187	146	131446	304900		1
	1	0	TPW	13 19 02	36.40	-74.50	9608						
A04	0	2		13 20 23	36.40	-74.15	9608	226	102	131746	322700		1
A05	1	2		13 25 25	36.40	-73.56	9608	226	102	132228	350900		1
A06	0	2		13 29 28	36.39	-72.95	9608	226	102	132631	375200		1
	1	0		13 34 33	36.39	-72.95	9608	170	259				
S10	0	1		13 35 03	36.39	-73.00	9608	170	259	133123	391400	634	12
S11	1	1		13 40 04	36.40	-73.56	9608	177	262	133625	421500	588	12
	1	0	TPW	13 47 22	36.42	-74.50	9608						
S12	1	2	CERC	13 50 31	36.58	-74.83	9608	177	?	134310	466500		12
	1	0		13 54 25	36.69	-74.82	9608	232	020				
	1	0		14 02 52	36.67	-74.78	9608	187	290				
	1	0		14 11 28	36.87	-75.29	6700	183	285				

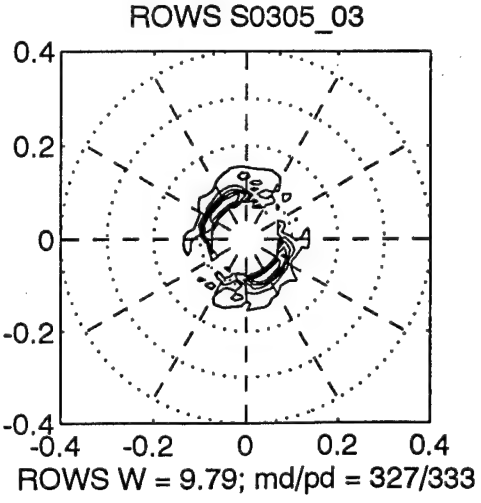
NOTES: (1) S02 HDG MAY BE 92 DEG OR BETWEEN 86 AND 92 DEG. (2) TIME AT TPS MAY ONLY BE APPROXIMATE AS WAS INSIDE TURN. (3) WP TEMP ESTIMATED FOR PLOTTING. (4) S09 ORIGINALLY BOMBED AT 16 MB; RERUN AS RESSCOM.RWS (ressac-compared-to-rows) AT 10 MB. (5) S12 NOT RUN BECAUSE OF UNCERTAIN HEADING. (6) S06 ORIGINALLY BOMBED--RERUN OK.

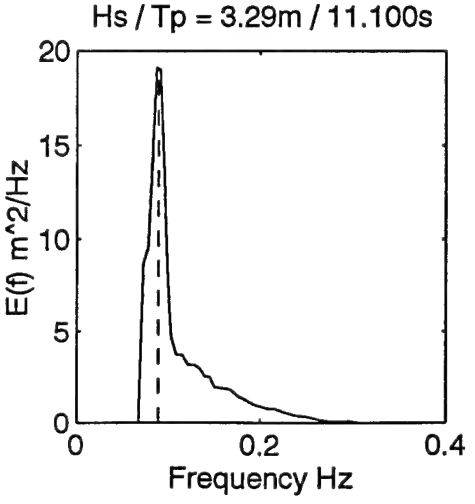

ROWS S0305_01
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 6.54; md/pd = 230/311

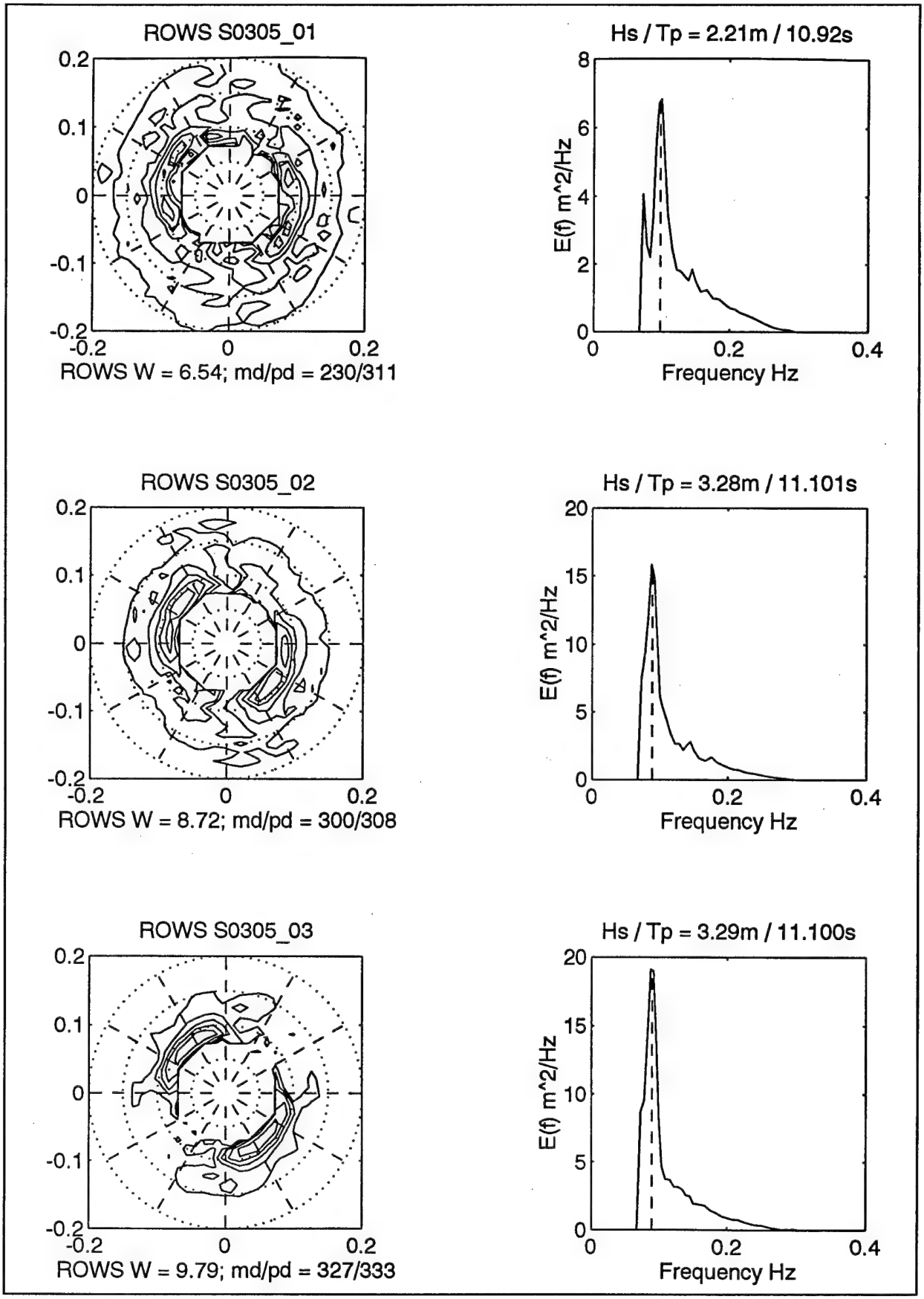

Hs / Tp = 2.21m / 10.92s
E(f) m^2/Hz
8
6
4
2
0
0 0.2 0.4
Frequency Hz

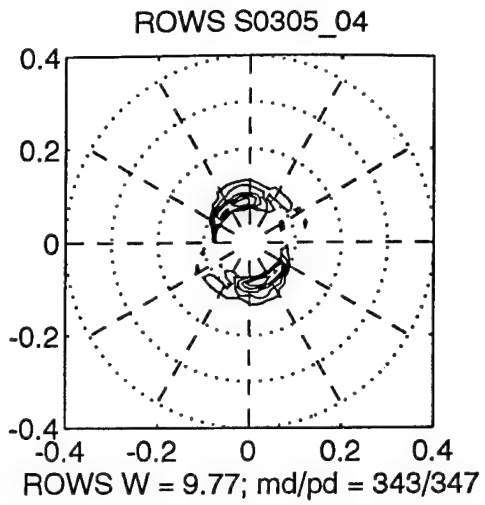

ROWS S0305_02
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 8.72; md/pd = 300/308

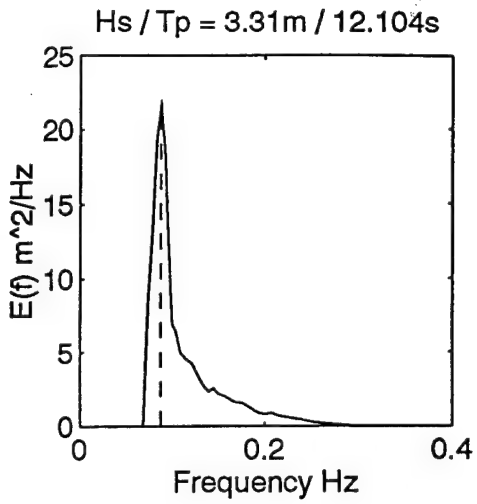

Hs / Tp = 3.28m / 11.101s
E(f) m^2/Hz
20
15
10
5
0
0 0.2 0.4
Frequency Hz

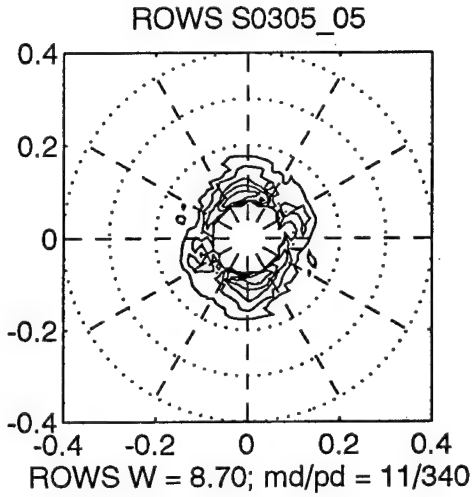

ROWS S0305_03
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 9.79; md/pd = 327/333

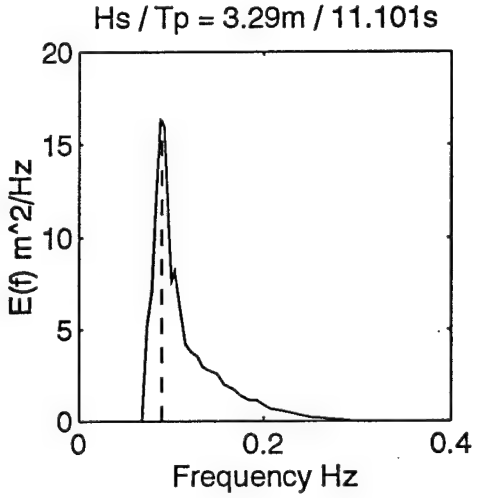

Hs / Tp = 3.29m / 11.100s
E(f) m^2/Hz
20
15
10
5
0
0 0.2 0.4
Frequency Hz

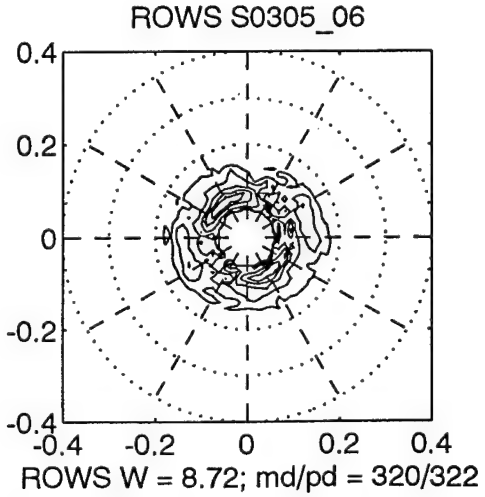

ROWS S0305_01
Hs / Tp = 2.21m / 10.92s
ROWS W = 6.54; md/pd = 230/311
E(f) m^2/Hz
Frequency Hz
ROWS S0305_02
Hs / Tp = 3.28m / 11.101s
ROWS W = 8.72; md/pd = 300/308
E(f) m^2/Hz
Frequency Hz
ROWS S0305_03
Hs / Tp = 3.29m / 11.100s
ROWS W = 9.79; md/pd = 327/333
E(f) m^2/Hz
Frequency Hz

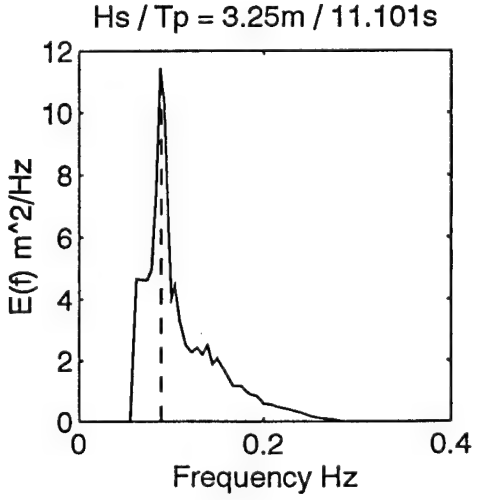

ROWS S0305_04
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 9.77; md/pd = 343/347

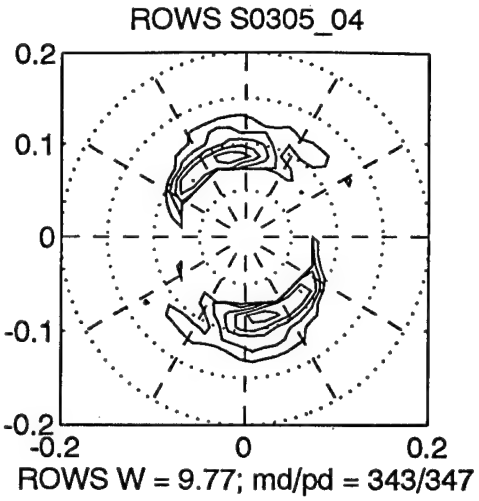

Hs / Tp = 3.31m / 12.104s
25
20
15
10
5
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz

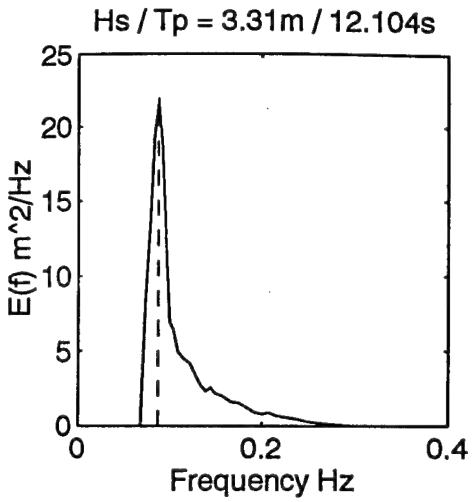

ROWS S0305_05
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 8.70; md/pd = 11/340

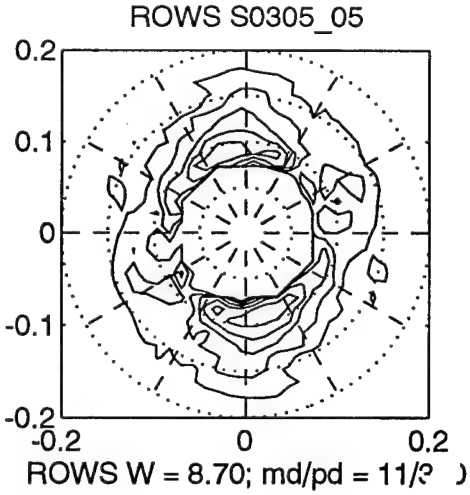

Hs / Tp = 3.29m / 11.101s
20
15
10
5
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz

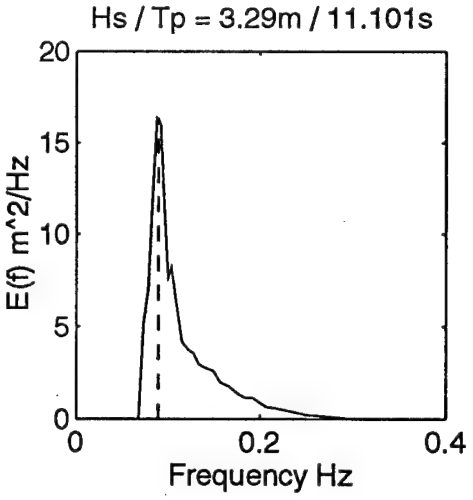

ROWS S0305_06
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 8.72; md/pd = 320/322

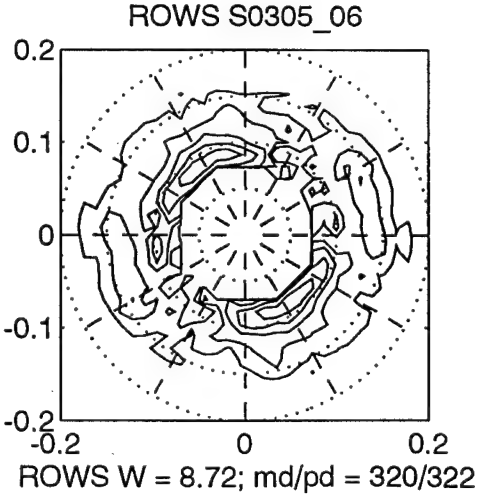

Hs / Tp = 3.25m / 11.101s
12
10
8
6
4
2
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz

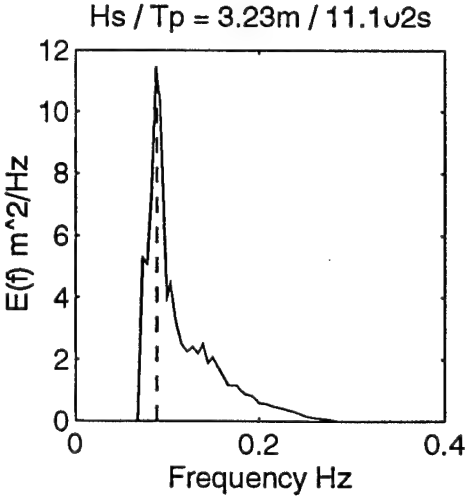

ROWS S0305_04
0.2
0.1
0
-0.1
-0.2
-0.2
0
0.2
ROWS W = 9.77; md/pd = 343/347

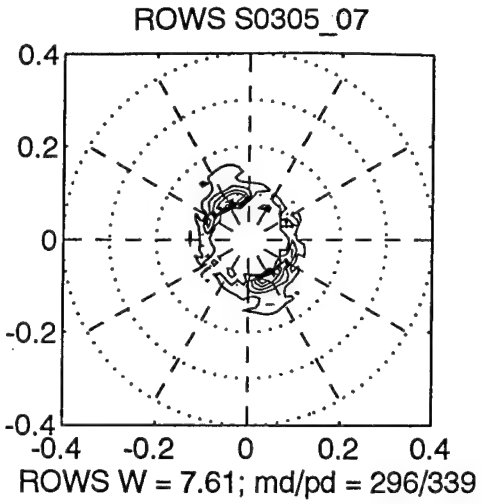

Hs / Tp = 3.31m / 12.104s
25
20
15
10
5
0
E(f) m^2/Hz
0
0.2
0.4
Frequency Hz

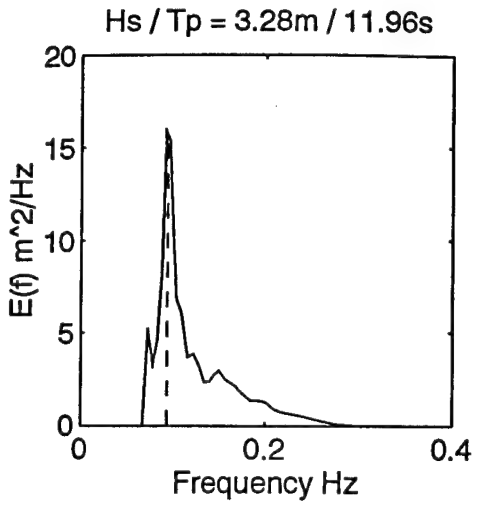

ROWS S0305_05
0.2
0.1
0
-0.1
-0.2
-0.2
0
0.2
ROWS W = 8.70; md/pd = 11/?

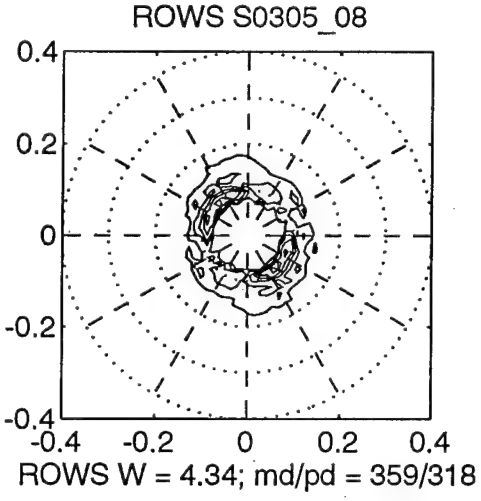

Hs / Tp = 3.29m / 11.101s
20
15
10
5
0
E(f) m^2/Hz
0
0.2
0.4
Frequency Hz

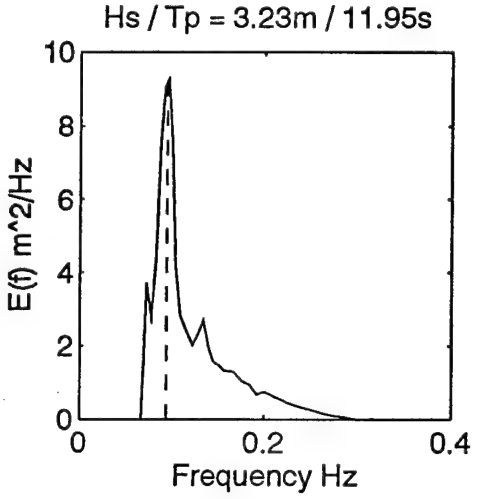

ROWS S0305_06
0.2
0.1
0
-0.1
-0.2
-0.2
0
0.2
ROWS W = 8.72; md/pd = 320/322

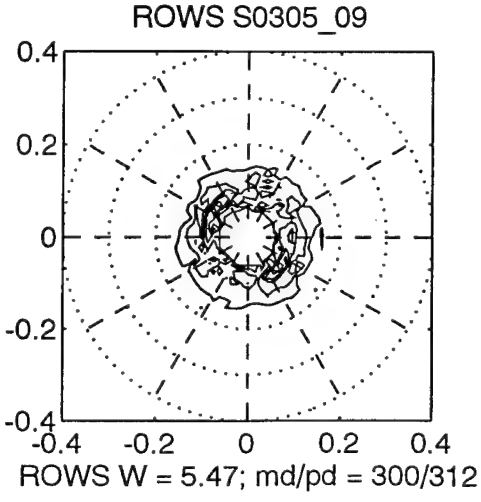

Hs / Tp = 3.23m / 11.1ʊ2s
12
10
8
6
4
2
0
E(f) m^2/Hz
0
0.2
0.4
Frequency Hz

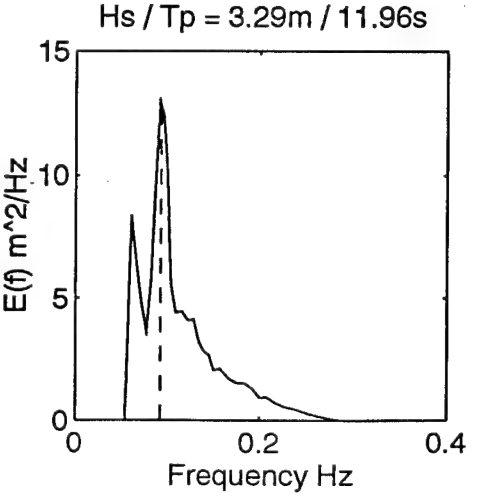

ROWS S0305_07
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 7.61; md/pd = 296/339

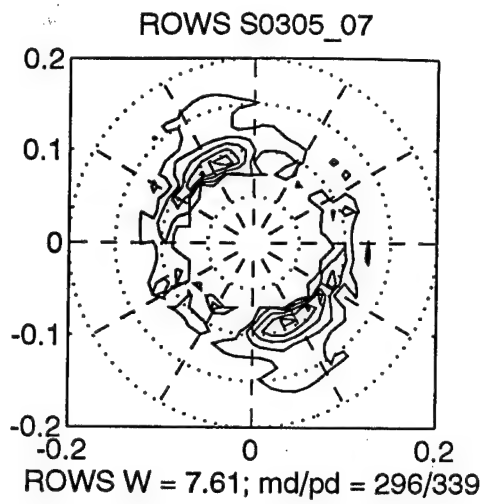

Hs / Tp = 3.28m / 11.96s
20
15
10
5
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz

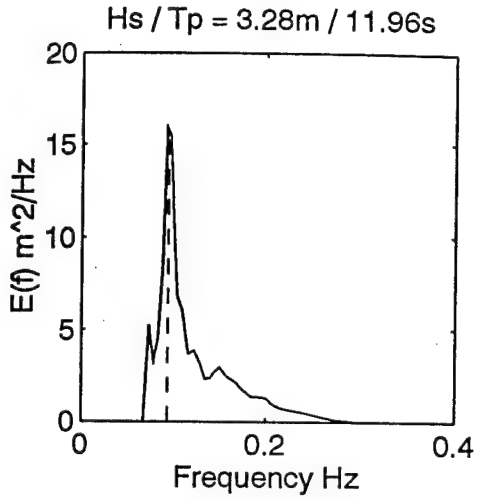

ROWS S0305_08
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 4.34; md/pd = 359/318

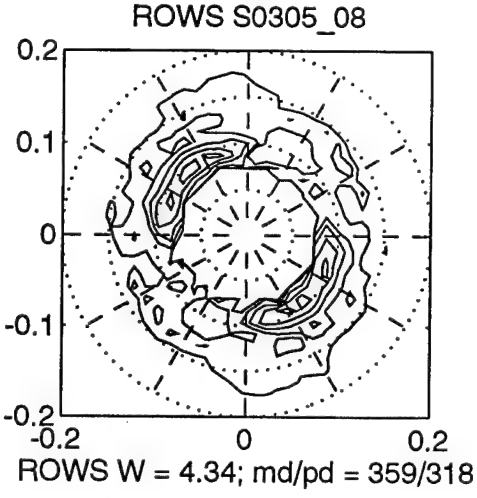

Hs / Tp = 3.23m / 11.95s
10
8
6
4
2
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz

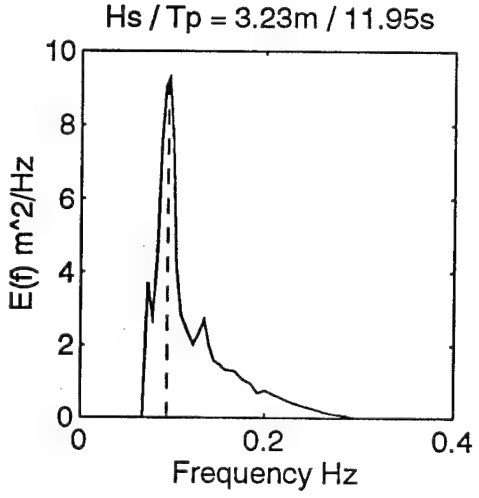

ROWS S0305_09
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 5.47; md/pd = 300/312

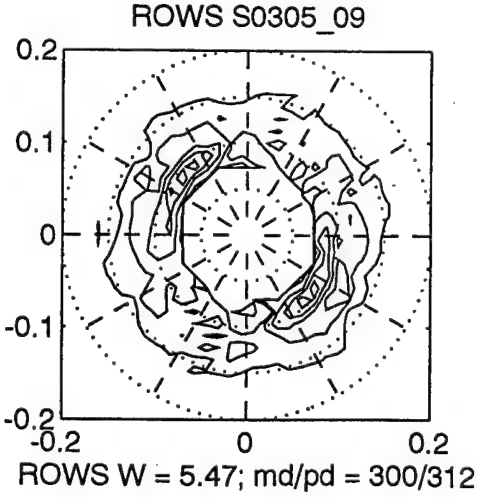

Hs / Tp = 3.29m / 11.96s
15
10
5
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz

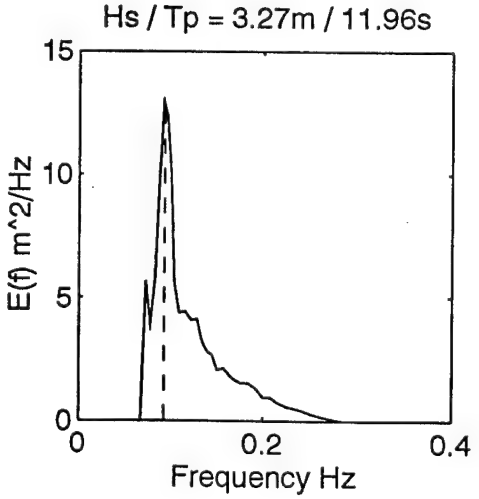

ROWS S0305_07
0.2
0.1
0
-0.1
-0.2
-0.2
0
0.2
ROWS W = 7.61; md/pd = 296/339

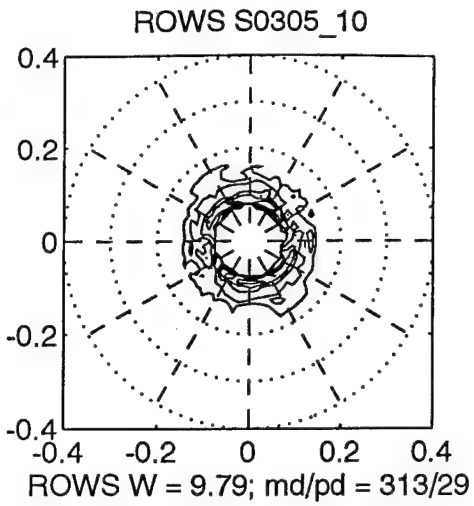

Hs / Tp = 3.28m / 11.96s
E(f) m^2/Hz
20
15
10
5
0
0
0.2
0.4
Frequency Hz

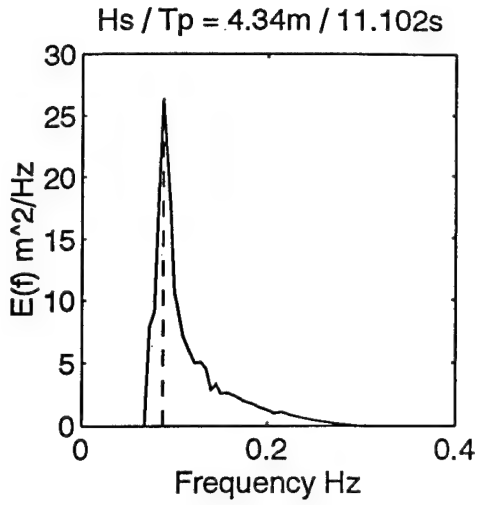

ROWS S0305_08
0.2
0.1
0
-0.1
-0.2
-0.2
0
0.2
ROWS W = 4.34; md/pd = 359/318

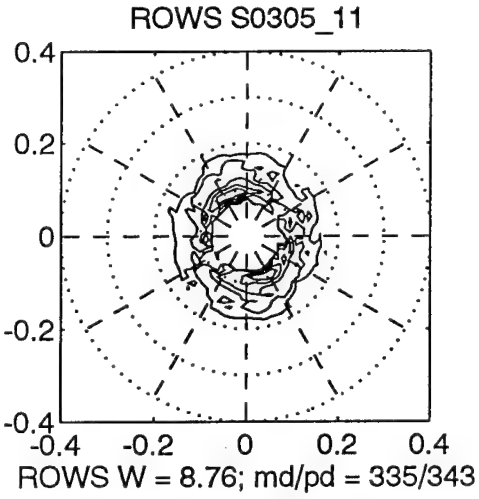

Hs / Tp = 3.23m / 11.95s
E(f) m^2/Hz
10
8
6
4
2
0
0
0.2
0.4
Frequency Hz

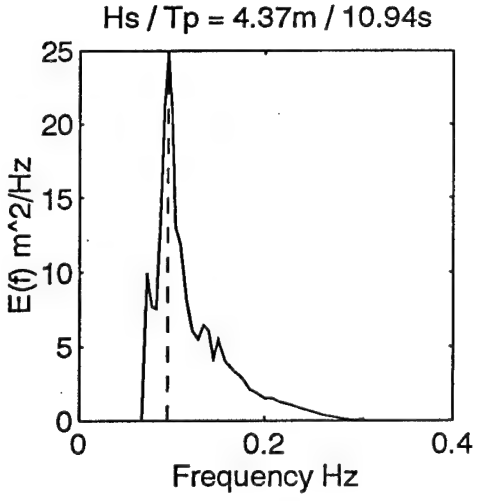

ROWS S0305_09
0.2
0.1
0
-0.1
-0.2
-0.2
0
0.2
ROWS W = 5.47; md/pd = 300/312

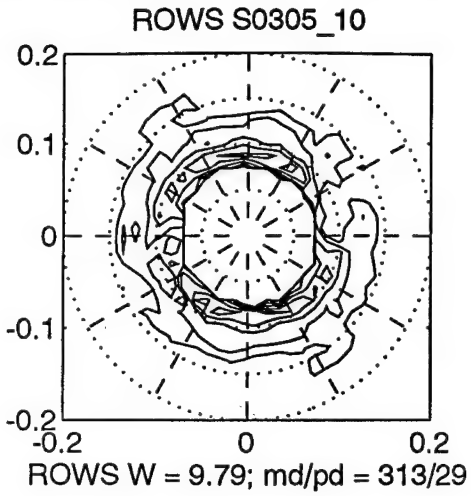

Hs / Tp = 3.27m / 11.96s
E(f) m^2/Hz
15
10
5
0
0
0.2
0.4
Frequency Hz

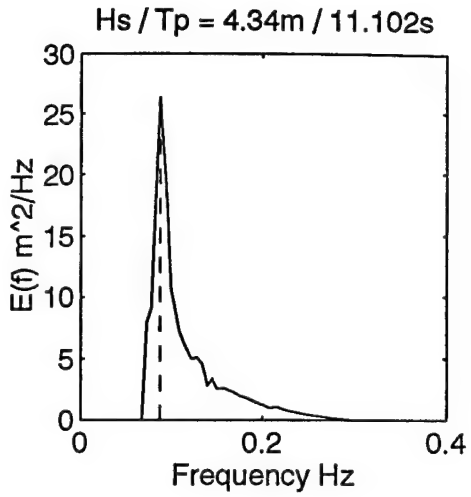

ROWS S0305_10
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 9.79; md/pd = 313/29

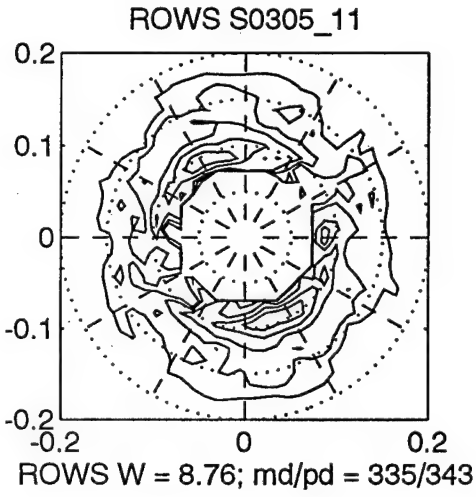

Hs / Tp = 4.34m / 11.102s
30
25
20
15
10
5
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz

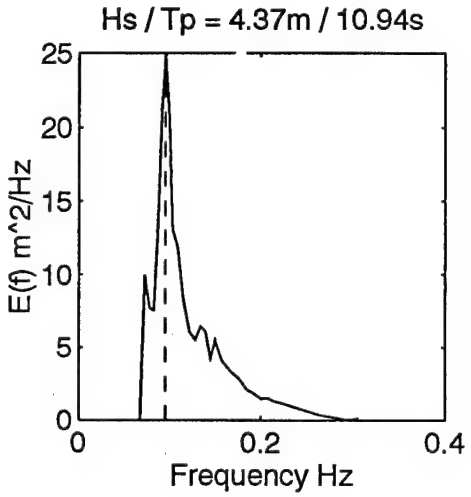

ROWS S0305_11
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 8.76; md/pd = 335/343

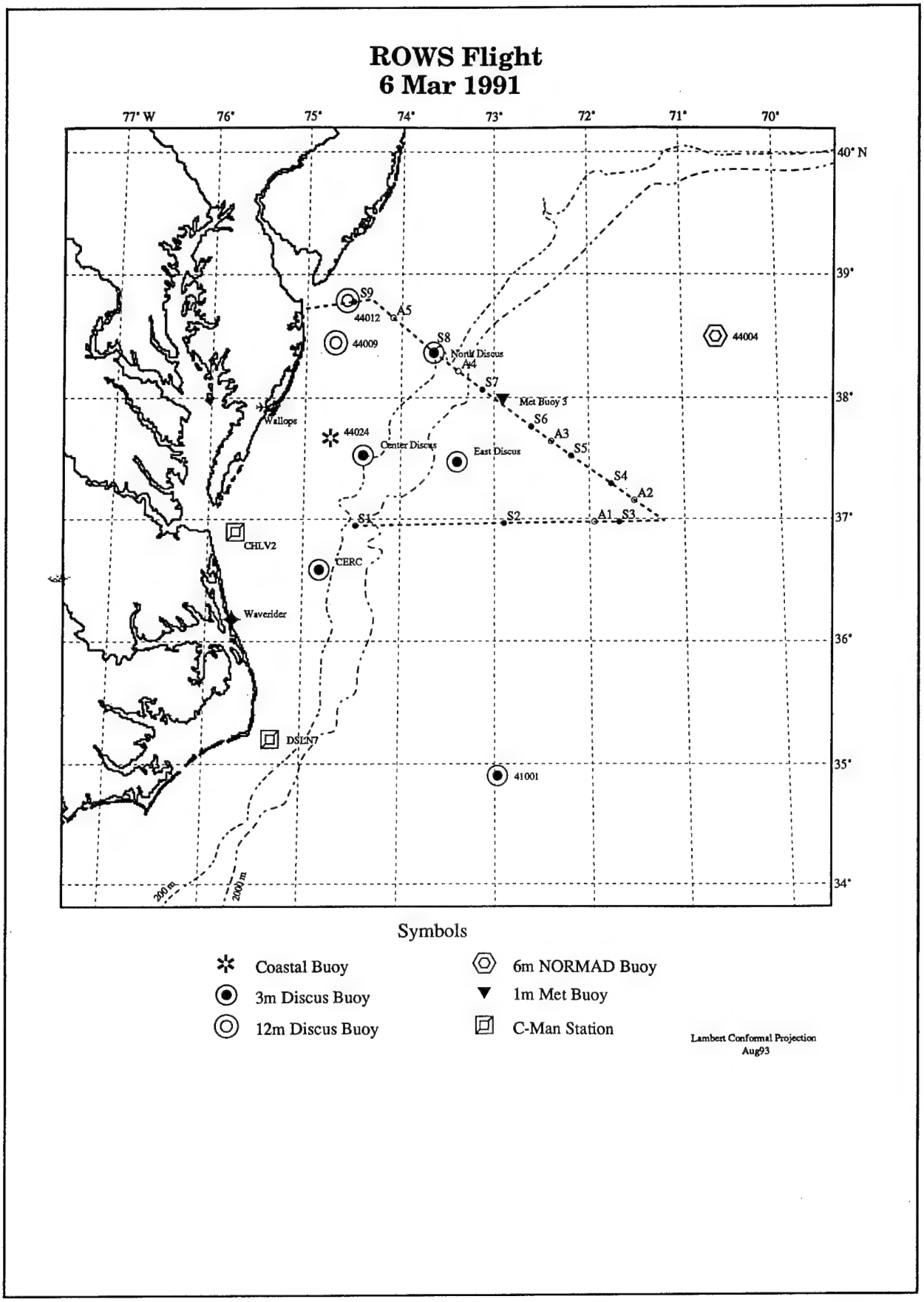

Hs / Tp = 4.37m / 10.94s
25
20
15
10
5
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz


ROWS S0305_10
0.2
0.1
0
-0.1
-0.2
-0.2
0
0.2
ROWS W = 9.79; md/pd = 313/29


Hs / Tp = 4.34m / 11.102s
30
25
20
15
10
5
0
E(f) m^2/Hz
0
0.2
0.4
Frequency Hz


ROWS S0305_11
0.2
0.1
0
-0.1
-0.2
-0.2
0
0.2
ROWS W = 8.76; md/pd = 335/343

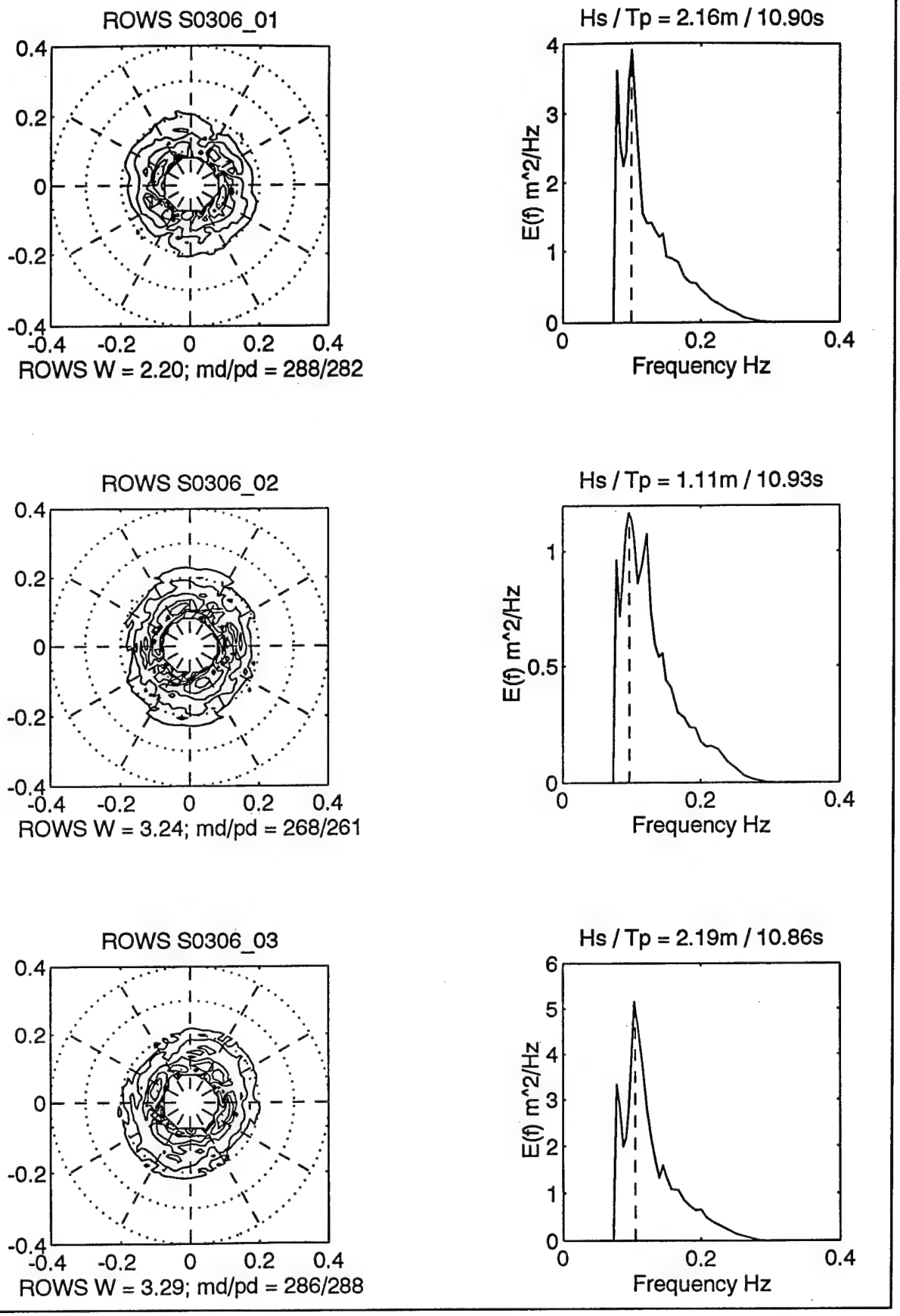

Hs / Tp = 4.37m / 10.94s
25
20
15
10
5
0
E(f) m^2/Hz
0
0.2
0.4
Frequency Hz

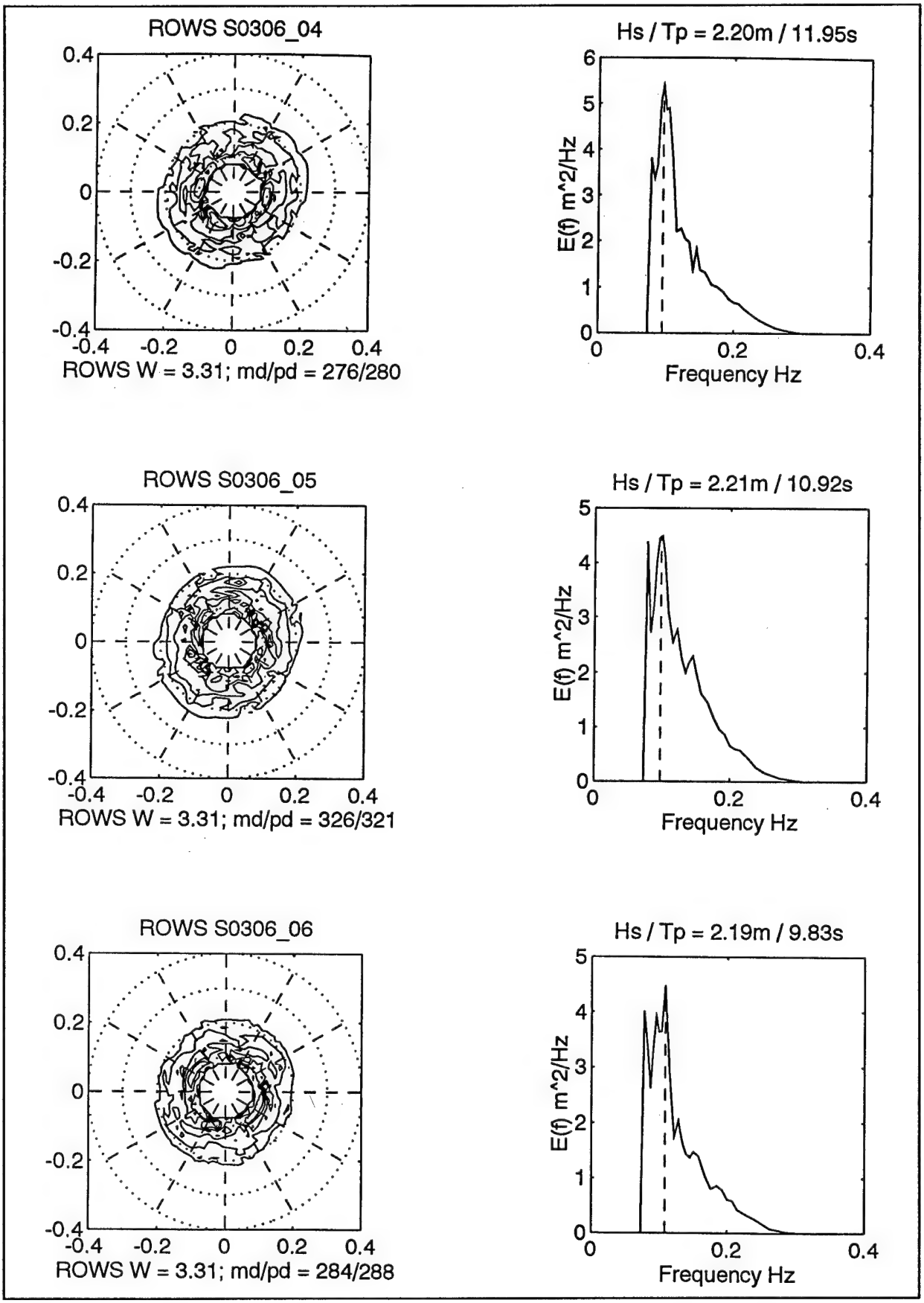

ROWS Flight
6 Mar 1991
77° W
76°
75°
74°
73°
72°
71°
70°
40° N
39°
38°
37°
36°
35°
34°
S9
44012
A5
44009
S8
North Discus
A4
S7
Met Buoy 3
S6
A3
S5
S4
A2
A1
S3
S2
S1
44004
Wallops
44024
Center Discus
East Discus
CHLV2
CERC
Waverider
DSLN7
41001
200 m
2000 m
Symbols
Coastal Buoy
3m Discus Buoy
12m Discus Buoy
6m NORMAD Buoy
1m Met Buoy
C-Man Station
Lambert Conformal Projection
Aug93

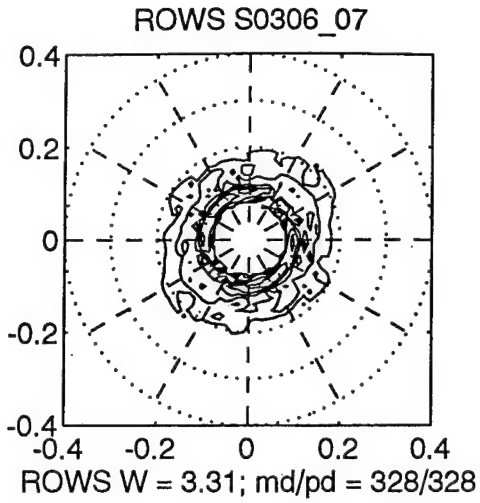
ROWS SWADE FLIGHT NAVIGATION AND FILE DATA
MAR 06, 1991

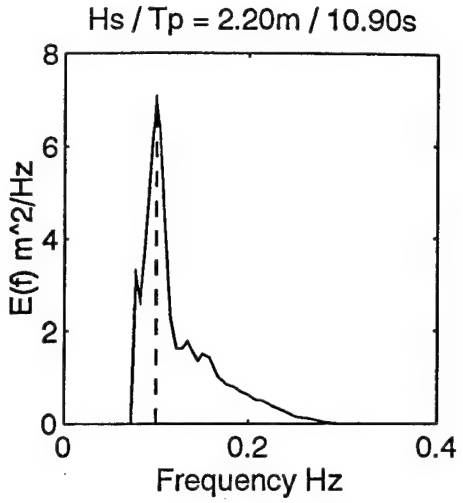
TAPE1/2 FILE	POS FIX	ROWS MODE	BUOY/ WP	EST HH MM SS	LAT	LON	ALT	SPD M/S	HDG TRU	PC-TIC START	REC # START	0 DEG DELTA	LEN ME
S01	1	1		14 32 10	36.95	-74.46	7075	209	083	142854	9301		12
TAPE2/2													
S02	1	1		14 43 08	36.97	-72.90	7075	209	088	144118	3801	1035	12
A01	0	2		14 50 10	36.98	-71.95	7075	209	088	144846	46901		1
S03	1	1		14 52 00	36.98	-71.69	7075	212	105	144933	50401	427	12
	1	0	TPE	14 54 00	36.99	-71.22	7075						
A02	0	2		14 58 27	37.17	-71.53	7075	166	308	145656	75601		1
S04	1	1		15 01 06	37.30	-71.77	7075	166	308	145826	83801	277	12
S05	0	1		15 05 56	37.53	-72.19	7075	162	308	150320	112901	119	12
A03	0	2		15 08 23	37.65	-72.40	7075	160	307	150649	132701		1
S06	1	1		15 10 49	37.77	-72.61	7075	157	307	150803	139801	536	12
S07	0	1		15 16 43	38.07	-73.13	7075	157	307	151407	175101	357	12
A04	0	2		15 19 33	38.22	-73.39	7075	157	307	151750	195101		1
S08	1	1	DIS-N	15 22 03	38.37	-73.65	7075	157	307	151932	203301	498	12
A05	0	2		15 27 11	38.65	-74.09	7075	157	307	152536	231601		1
	1	0	A	15 29 54	38.80	-74.32	6710	158	265				
	1	0		15 31 55	38.78	-74.48	6710	158	265				
S09	1	1		15 32 30	38.78	-74.51	6710	158	265	152947	253301	312	12
	1	0	COAST	15 37 14	38.72	-75.07	6710						

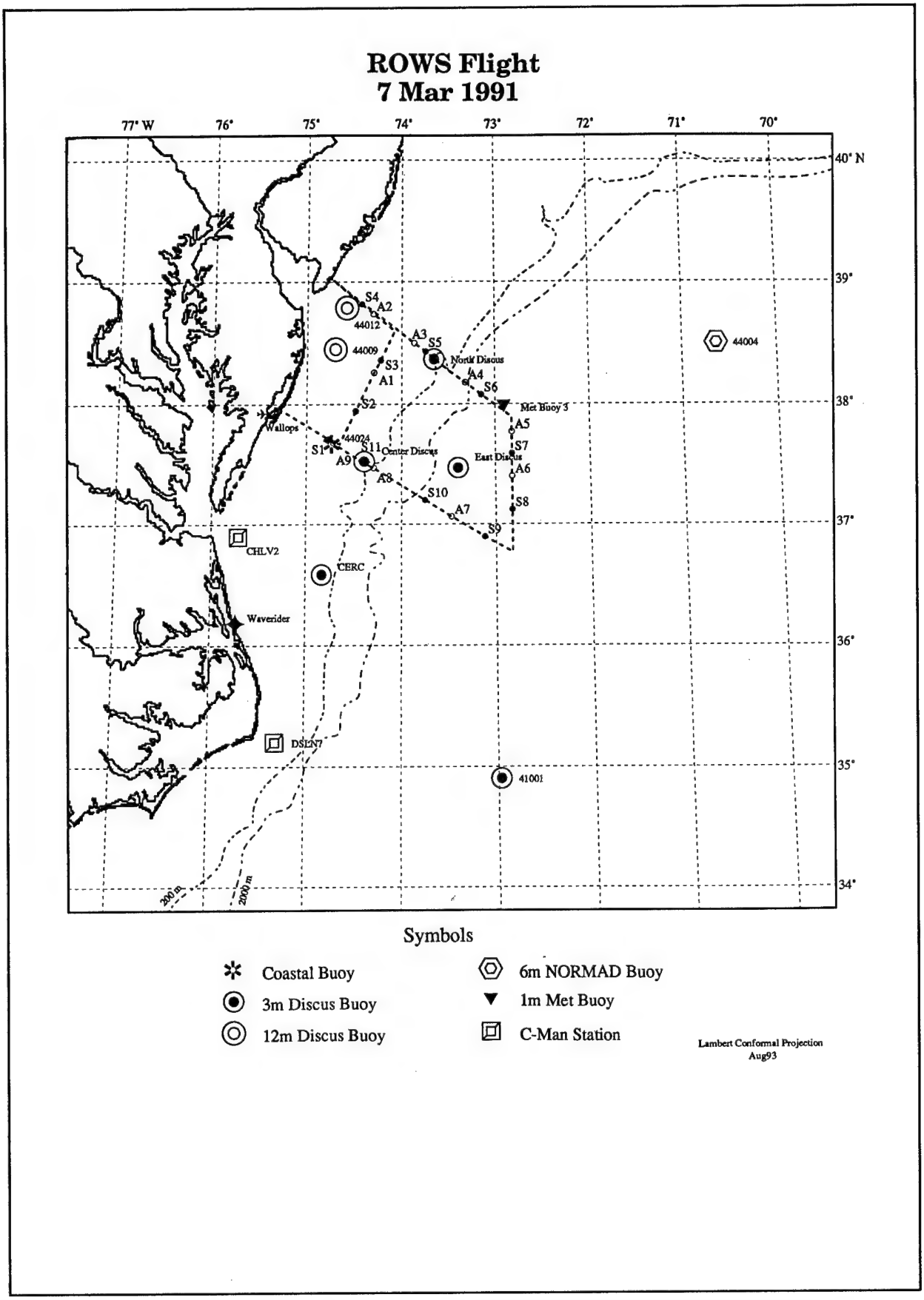
NOTES: (1) S08 AND S09 SKIPPED BECAUSE OF STRANGE TIME TAGS AND BAD A/C ROLLS.


ROWS S0306_01
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 2.20; md/pd = 288/282
Hs / Tp = 2.16m / 10.90s
E(f) m^2/Hz
0 1 2 3 4
0 0.2 0.4
Frequency Hz
ROWS S0306_02
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 3.24; md/pd = 268/261
Hs / Tp = 1.11m / 10.93s
E(f) m^2/Hz
0 0.5 1
0 0.2 0.4
Frequency Hz
ROWS S0306_03
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 3.29; md/pd = 286/288
Hs / Tp = 2.19m / 10.86s
E(f) m^2/Hz
0 1 2 3 4 5 6
0 0.2 0.4
Frequency Hz


ROWS S0306_04
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 3.31; md/pd = 276/280
Hs / Tp = 2.20m / 11.95s
E(f) m^2/Hz
0 1 2 3 4 5 6
0 0.2 0.4
Frequency Hz
ROWS S0306_05
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 3.31; md/pd = 326/321
Hs / Tp = 2.21m / 10.92s
E(f) m^2/Hz
0 1 2 3 4 5
0 0.2 0.4
Frequency Hz
ROWS S0306_06
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 3.31; md/pd = 284/288
Hs / Tp = 2.19m / 9.83s
E(f) m^2/Hz
0 1 2 3 4 5
0 0.2 0.4
Frequency Hz


ROWS S0306_07
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 3.31; md/pd = 328/328

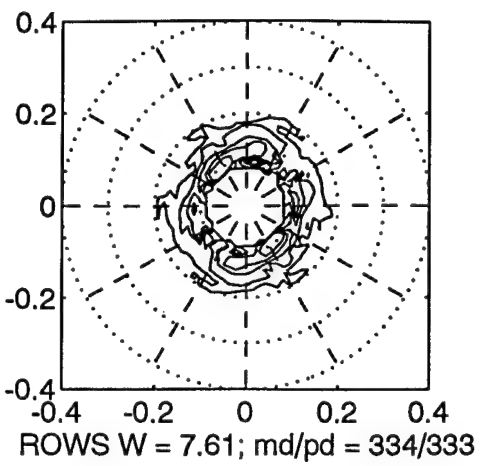

Hs / Tp = 2.20m / 10.90s
8
6
4
2
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz

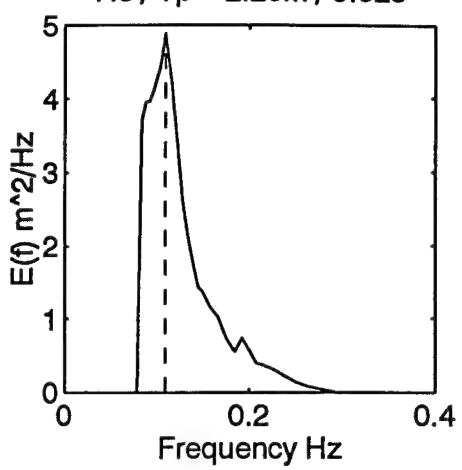

ROWS Flight
7 Mar 1991
77° W
76°
75°
74°
73°
72°
71°
70°
40° N
39°
38°
37°
36°
35°
34°
S4
A2
44012
A3
S5
44009
S3
A1
North Discus
A4
S6
44004
S2
Met Buoy 3
A5
Wallops
S1
44024
S11
A9
Center Discus
East Discus
S7
A6
A8
S10
A7
S8
S9
CHLV2
CERC
Waverider
DSLN7
41001
200 m
2000 m
Symbols
Coastal Buoy
3m Discus Buoy
12m Discus Buoy
6m NORMAD Buoy
1m Met Buoy
C-Man Station
Lambert Conformal Projection
Aug93

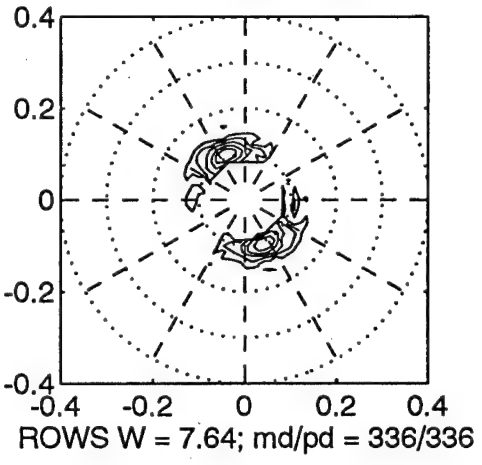
ROWS SWADE FLIGHT NAVIGATION AND FILE DATA
MAR 07, 1991--FLIGHT #1

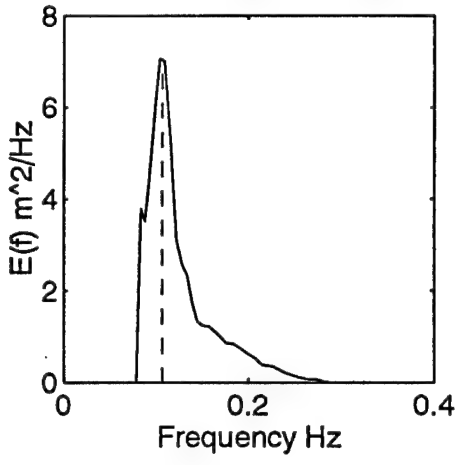
TAPE1/2 FILE	POS FIX	ROWS MODE	BUOY/ WP	EST HH	MM	SS	LAT	LON	ALT M	SPD M/S	HDG TRU	PC-TIC START	REC # START	0 DEG DELTA	LEN ME
	0	0	TEMP				37.97	-75.30							
S01	0	1		17	04	26	37.72	-74.77	4575	200	130	170129	101	939	9
	1	0	EXP	17	05	09	37.69	-74.72							
	0	0	TEMP				37.68	-74.65							
	1	0		17	11	00	37.84	-74.55	4575	148	015				
S02	0	1		17	12	29	37.95	-74.48	4575	148	015	170857	28601	565	12
A01	0	2		17	16	50	38.26	-74.29	4575	148	015	171414	59701		1
S03	0	1		17	18	24	38.36	-74.22	4575	148	015	171459	63801	334	12
	1	0		17	19	24	38.44	-74.17							
	1	0	TP1	17	20	50	38.60	-74.07							
A02	0	2		17	24	55	38.74	-74.30	4575	132	309	172213	106701		1
S04	1	1		17	26	36	38.82	-74.42	4575	132	309	172253	110401	891	12
TAPE2/2															
	0	0	TEMP				39.04	-74.77	7625	227	133				
A03	0	2		17	47	30	38.50	-73.86	7625	227	133	174612	30901		1
S05	0	1		17	48	40	38.43	-73.74	7625	227	133	174636	32801	377	9
	1	0	DIS-N	17	49	22	38.37	-73.65	7625	227	133				
	1	0		17	51	17	38.26	-73.47	7625	227	133				
A04	0	2		17	52	30	38.18	-73.32	7625	227	133	175110	57301		1
S06	0	1		17	53	50	38.08	-73.15	7625	227	133	175145	60301	289	9
	1	0	TP2	17	55	08	37.90	-72.83	7625						
A05	0	2		17	57	04	37.78	-72.83	7625	189	190	175540	83001		1
S07	0	1		17	58	59	37.60	-72.83	7625	189	190	175639	88601	836	12
	1	0		17	59	39	37.50	-72.83	7625	189	190				
A06	0	2		18	01	04	37.41	-72.84	7625	189	190	175937	106001		1
S08	1	1		18	03	50	37.13	-72.83	7625	189	190	180128	116601	927	12
	1	0	TP3	18	05	54	36.78	-72.83	7625						
S09	0	1		18	10	12	36.90	-73.12	7625	119	293	180800	155701	747	12
A07	0	2		18	16	12	37.07	-73.47	7625	119	293	181447	195901		1
S10	1	1		18	20	06	37.21	-73.75	7625	119	293	181750	213701	637	12
A08	0	2		18	27	49	37.48	-74.29	7625	119	293	182623	263901		1
	1	0	DIS-C	18	29	05	37.52	-74.39	7625	124	296				
S11	0	1		18	29	40	37.54	-74.42	7625	124	296	182648	266101	818	18
	1	0		18	31	25	37.59	-74.53	7625	124	296				
A09	0	2	EXP	18	34	12	37.69	-74.72	7625	124	296	183246	301501		3
	0	0	U-TURN	18	35	00									
	1	0	DIS-C	18	39	20	37.54	-74.39	7625	242	132				
	1	0		18	47	17	37.02	-73.33	7625	242	132				
	0	0	U-TURN	18	49	25									
	1	0		19	00	35	37.14	-73.56	7625	124	295				
	1	0		19	12	09	37.54	-74.39							
	1	0	DIS-C	19	12	09									

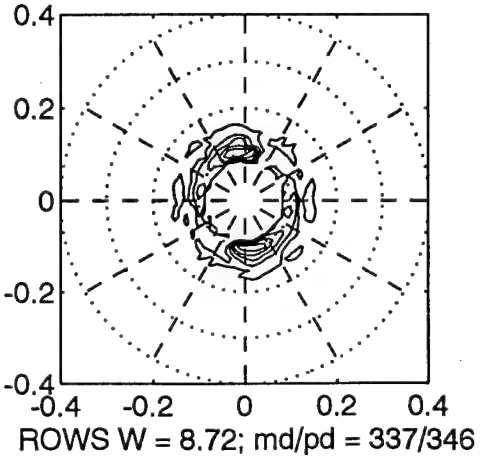
NOTES: (1) REVERSE COURSE DATA AFTER 183500 OMITTED AND TRACK NOT PLOTTED.

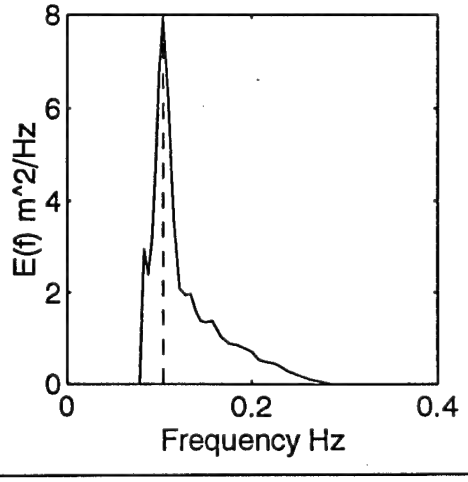

ROWS S0307a01
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 7.61; md/pd = 334/333

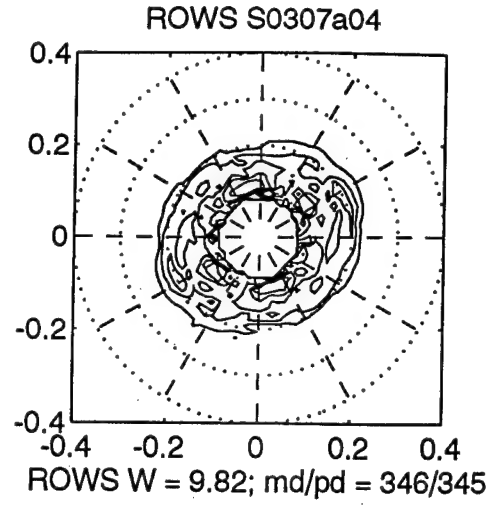

Hs / Tp = 2.20m / 9.82s
E(f) m^2/Hz
5
4
3
2
1
0
0 0.2 0.4
Frequency Hz

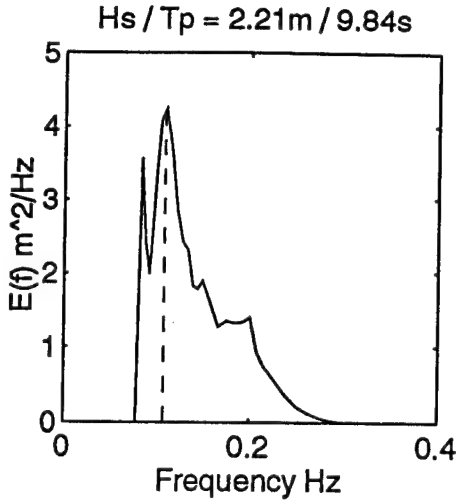

ROWS S0307a02
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 7.64; md/pd = 336/336

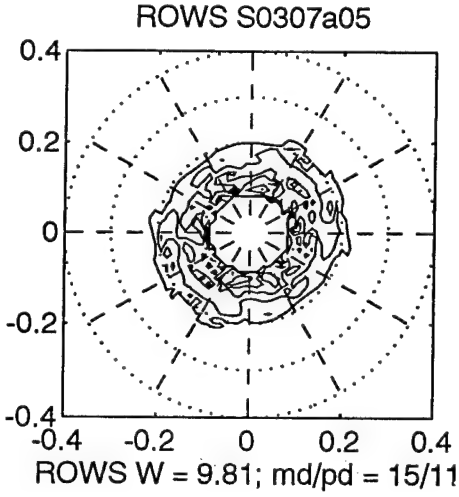

Hs / Tp = 2.21m / 9.85s
E(f) m^2/Hz
8
6
4
2
0
0 0.2 0.4
Frequency Hz

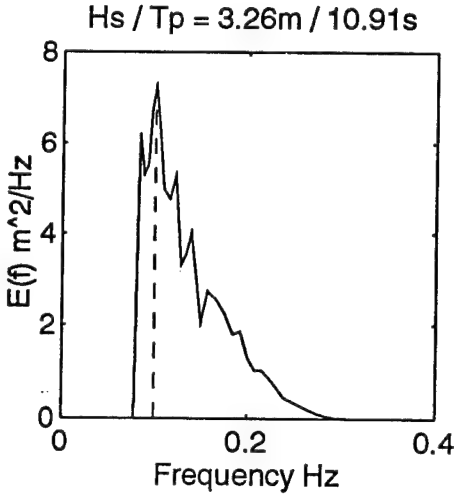

ROWS S0307a03
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 8.72; md/pd = 337/346

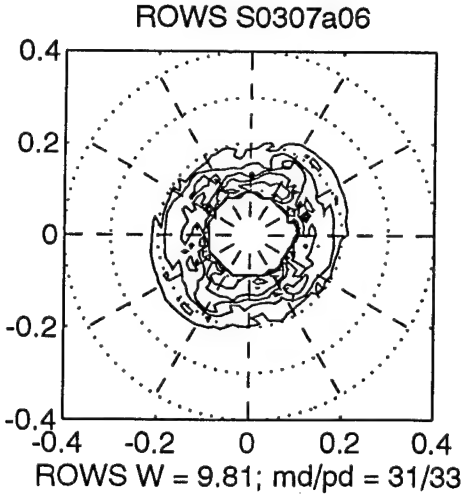

Hs / Tp = 2.20m / 10.86s
E(f) m^2/Hz
8
6
4
2
0
0 0.2 0.4
Frequency Hz

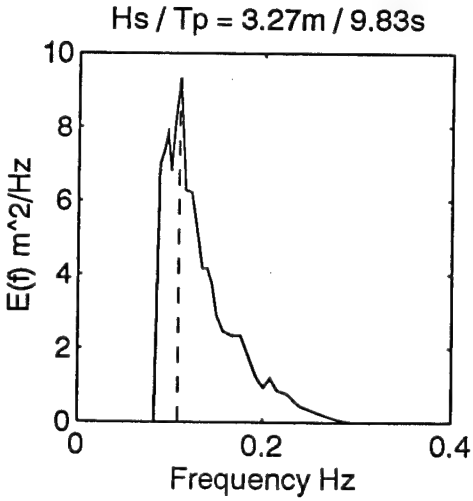

ROWS S0307a04
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 9.82; md/pd = 346/345

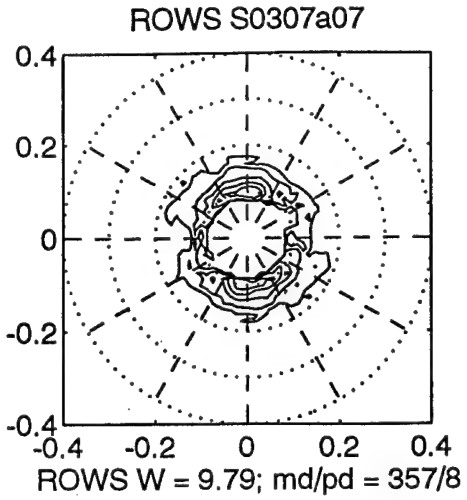

Hs / Tp = 2.21m / 9.84s
E(f) m^2/Hz
5
4
3
2
1
0
0 0.2 0.4
Frequency Hz

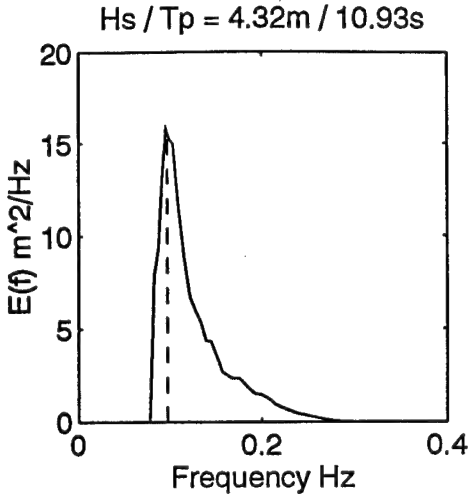

ROWS S0307a05
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 9.81; md/pd = 15/11

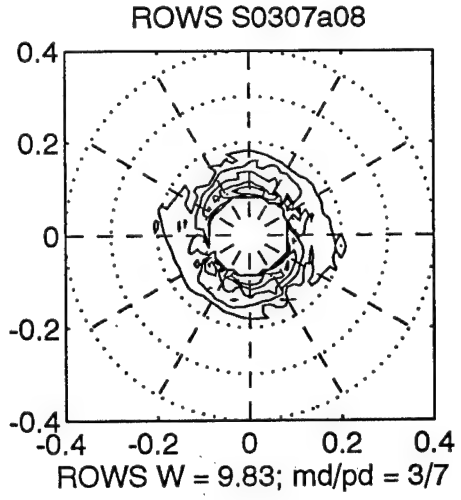

Hs / Tp = 3.26m / 10.91s
E(f) m^2/Hz
8
6
4
2
0
0 0.2 0.4
Frequency Hz

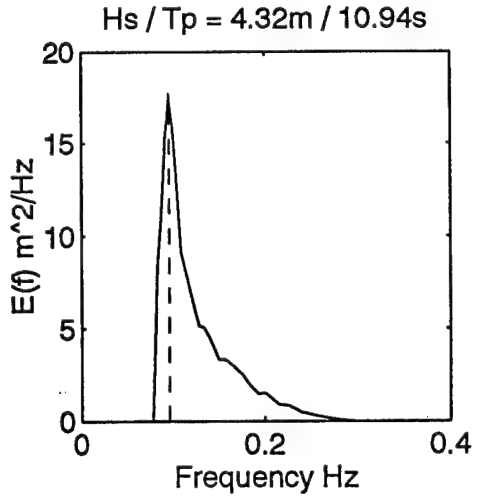

ROWS S0307a06
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 9.81; md/pd = 31/33

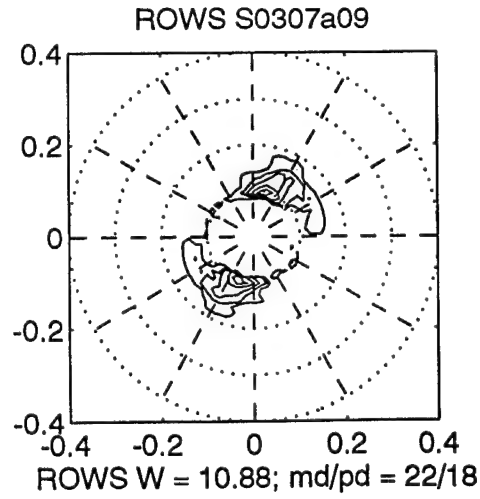

Hs / Tp = 3.27m / 9.83s
E(f) m^2/Hz
10
8
6
4
2
0
0 0.2 0.4
Frequency Hz

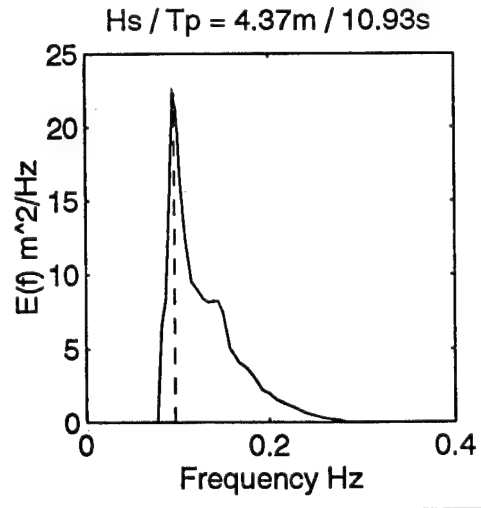

ROWS S0307a07
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 9.79; md/pd = 357/8

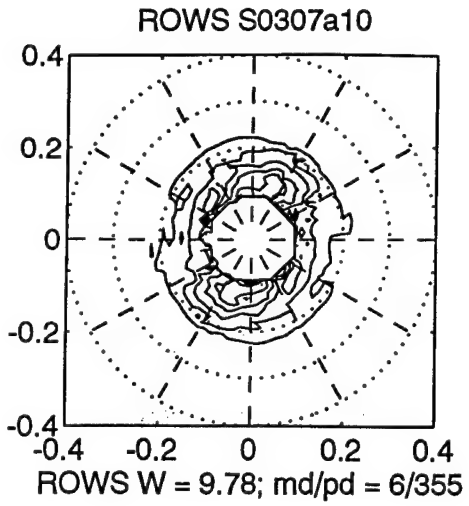

Hs / Tp = 4.32m / 10.93s
E(f) m^2/Hz
20
15
10
5
0
0 0.2 0.4
Frequency Hz

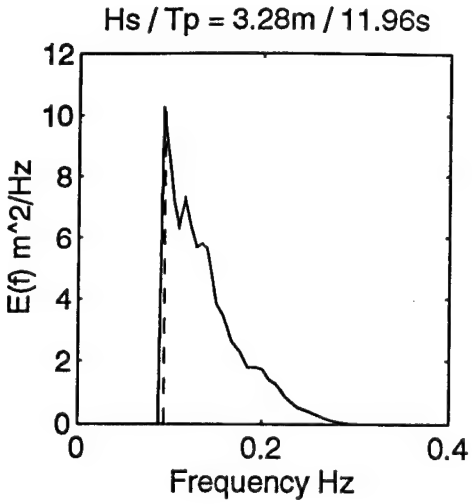

ROWS S0307a08
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 9.83; md/pd = 3/7

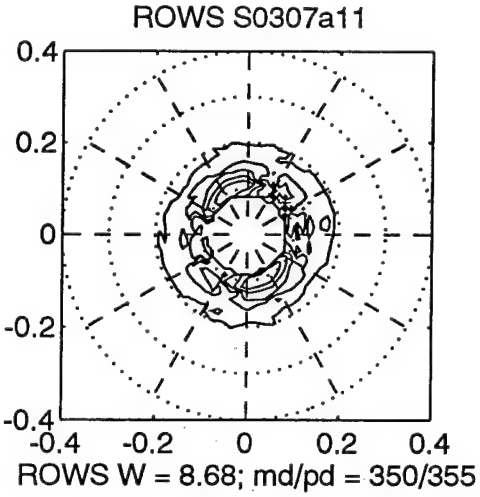

Hs / Tp = 4.32m / 10.94s
E(f) m^2/Hz
20
15
10
5
0
0 0.2 0.4
Frequency Hz

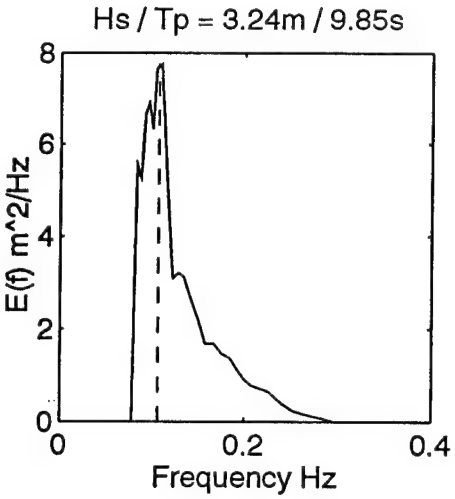

ROWS S0307a09
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 10.88; md/pd = 22/18


Hs / Tp = 4.37m / 10.93s
E(f) m^2/Hz
25
20
15
10
5
0
0 0.2 0.4
Frequency Hz


ROWS S0307a10
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 9.78; md/pd = 6/355


Hs / Tp = 3.28m / 11.96s
12
10
8
6
4
2
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz


ROWS S0307a11
0.4
0.2
0
-0.2
-0.4
-0.4 -0.2 0 0.2 0.4
ROWS W = 8.68; md/pd = 350/355


Hs / Tp = 3.24m / 9.85s
8
6
4
2
0
E(f) m^2/Hz
0 0.2 0.4
Frequency Hz

Appendix F
Daily Weather Maps

The figures found in thix appendix are derived from weekly publications by the National Oceanic and Atmospheric Administration, National Weather Service, and the National Meteorological Center Climate Analysis Center. They are based on operational surface weather analyses. Each figure represents the fronts, pressure centers, and observations at 7:00 a.m. E.S.T. for each day displayed in the figure caption. Precipitation is indicated by the shaded area. Movement of large low pressure centers is indicated by lines designated with arrowheads. Origin of movement is identified by a small box.

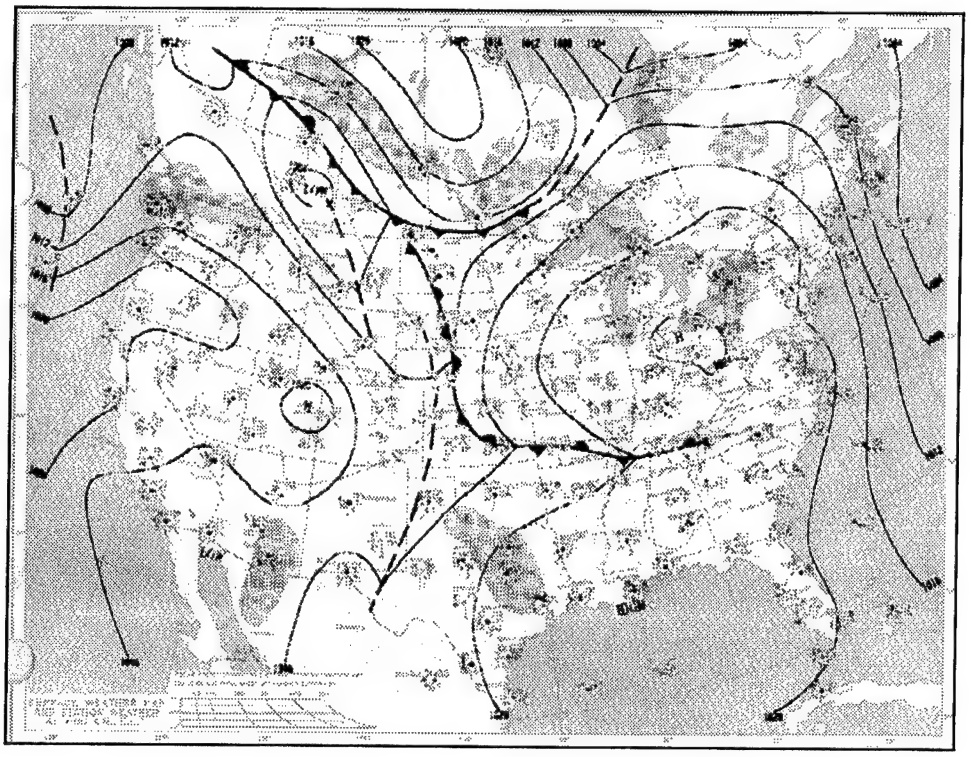
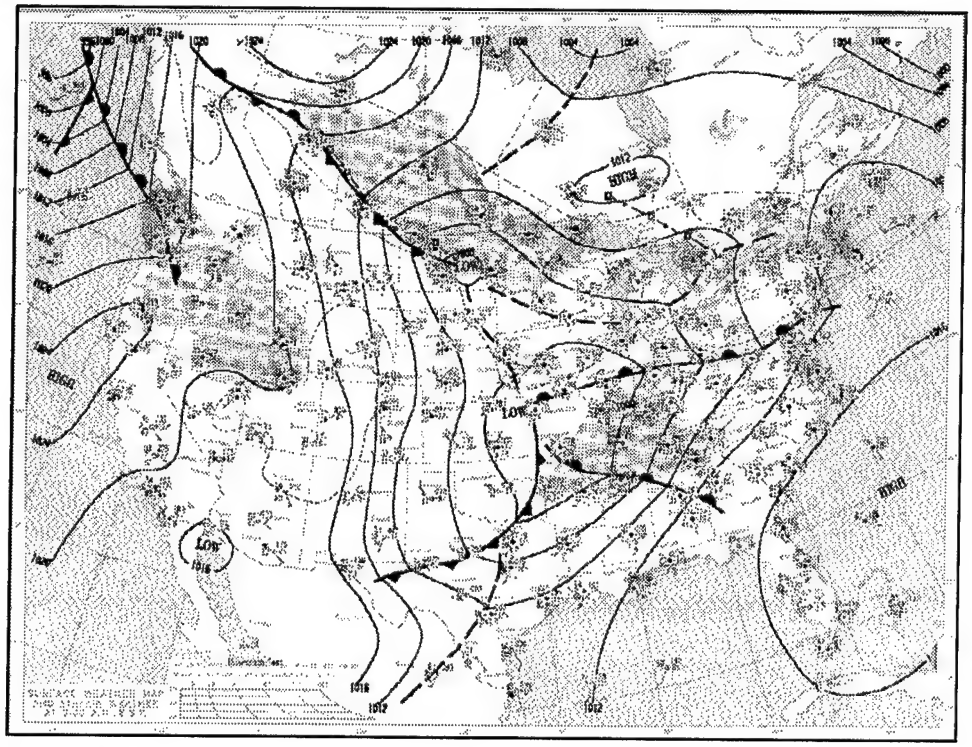


Figure F1. 12 February 1991



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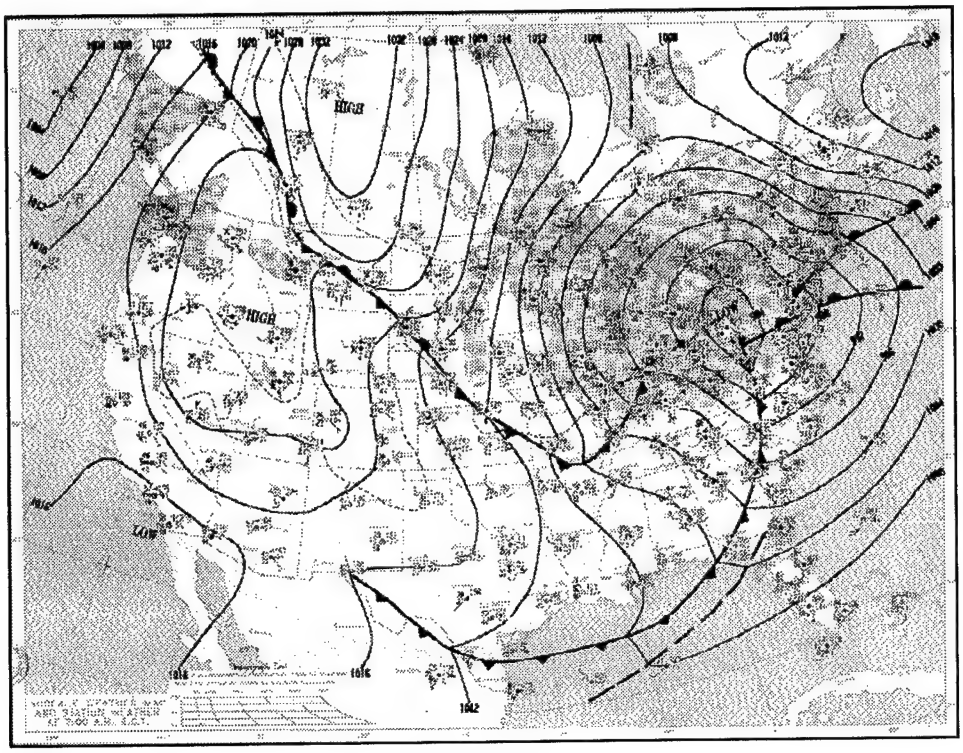


Figure F3. 14 February 1991

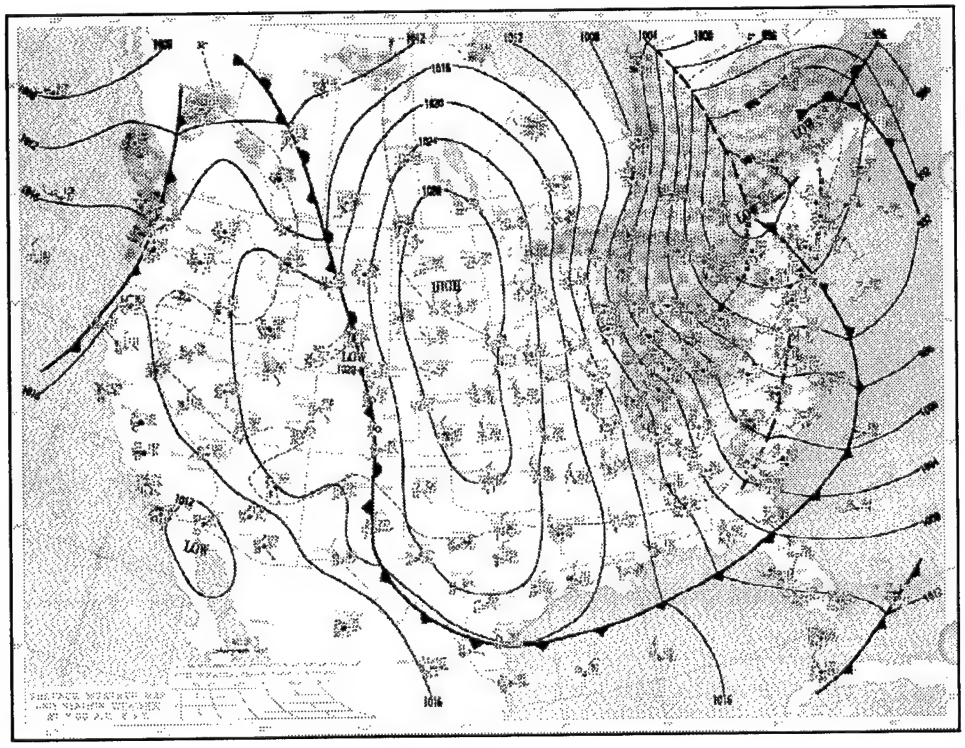


Figure F4. 15 February 1991

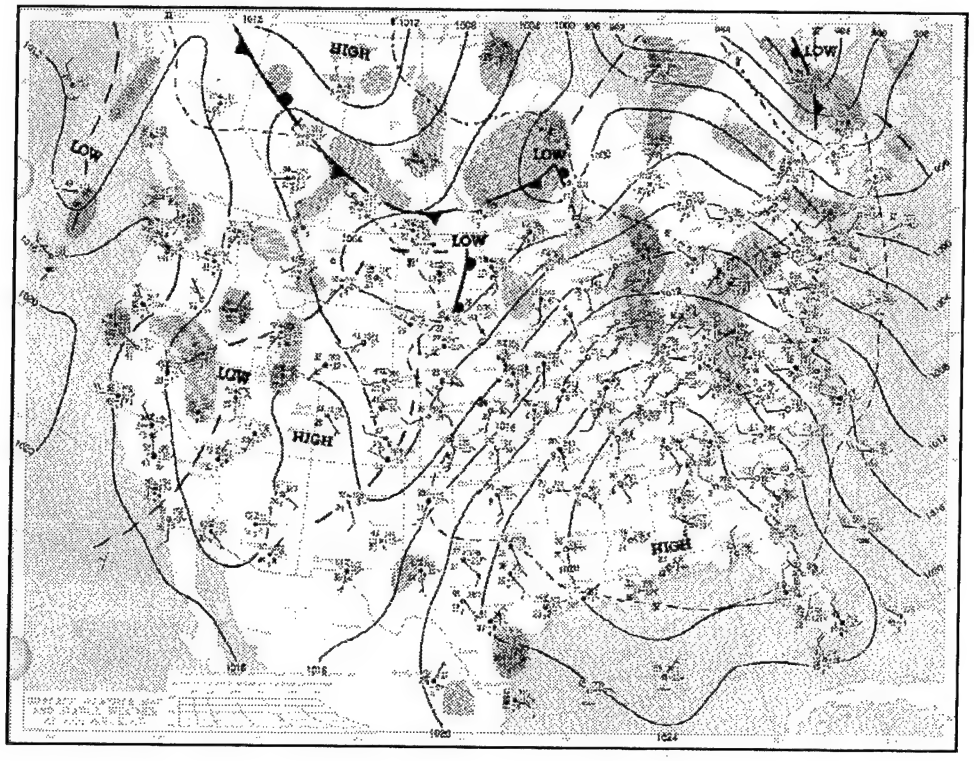


Figure F5. 16 February 1991

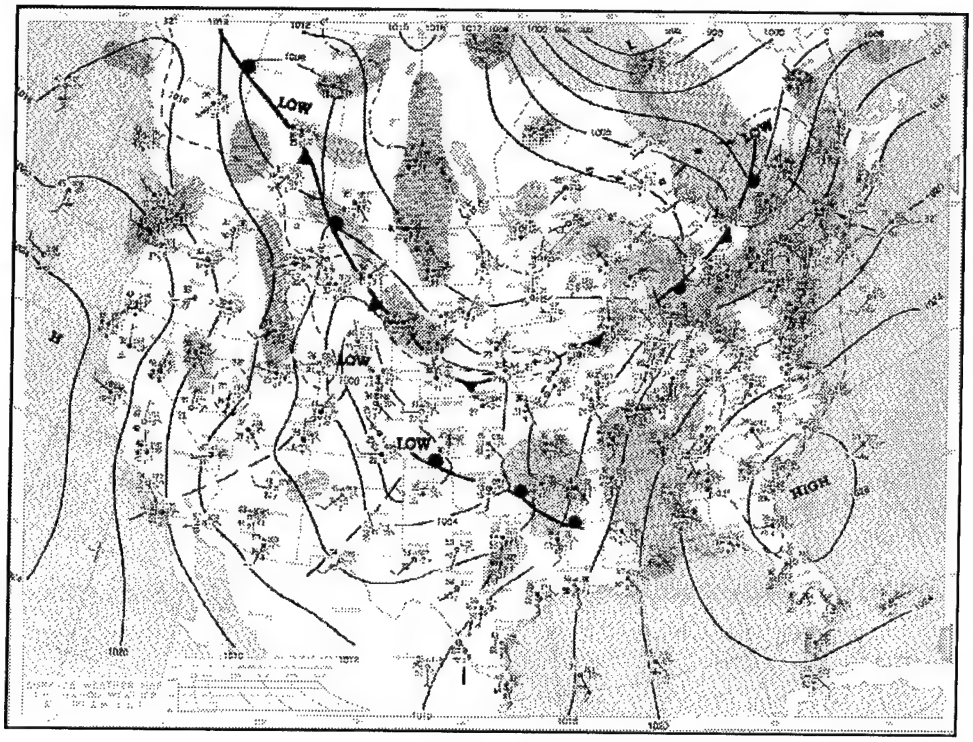
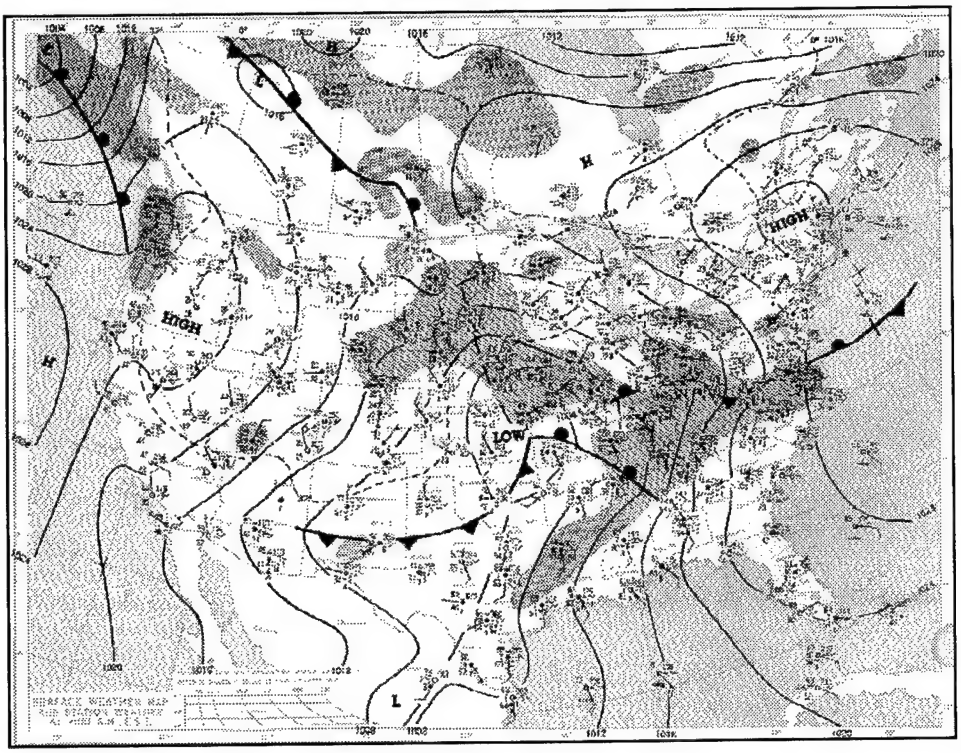


Figure F6. 17 February 1991



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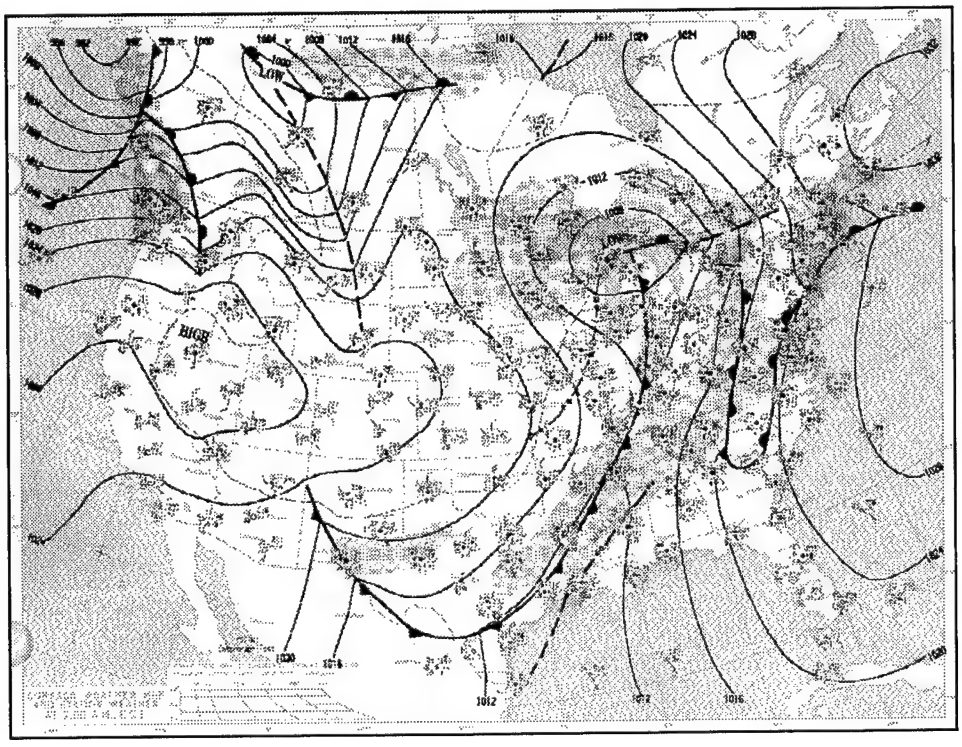

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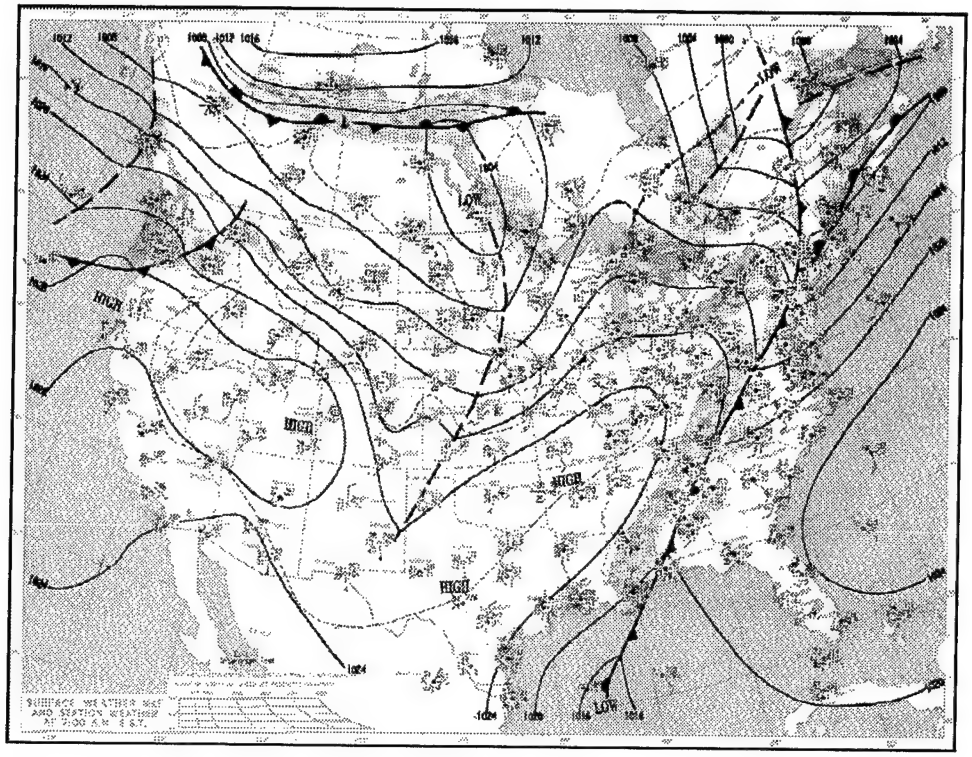

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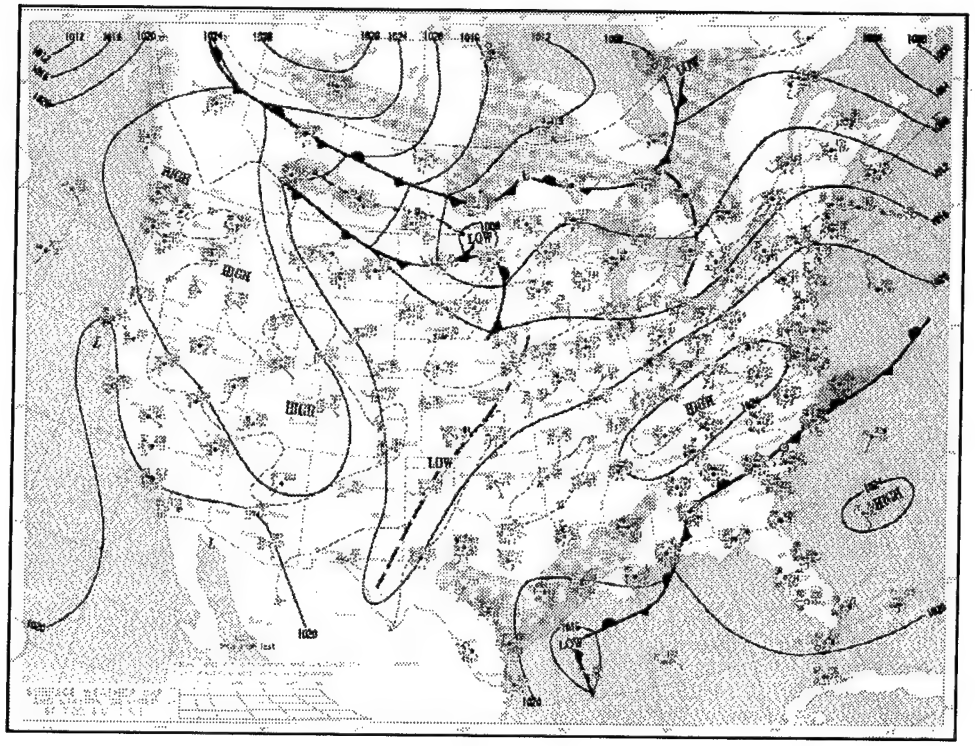

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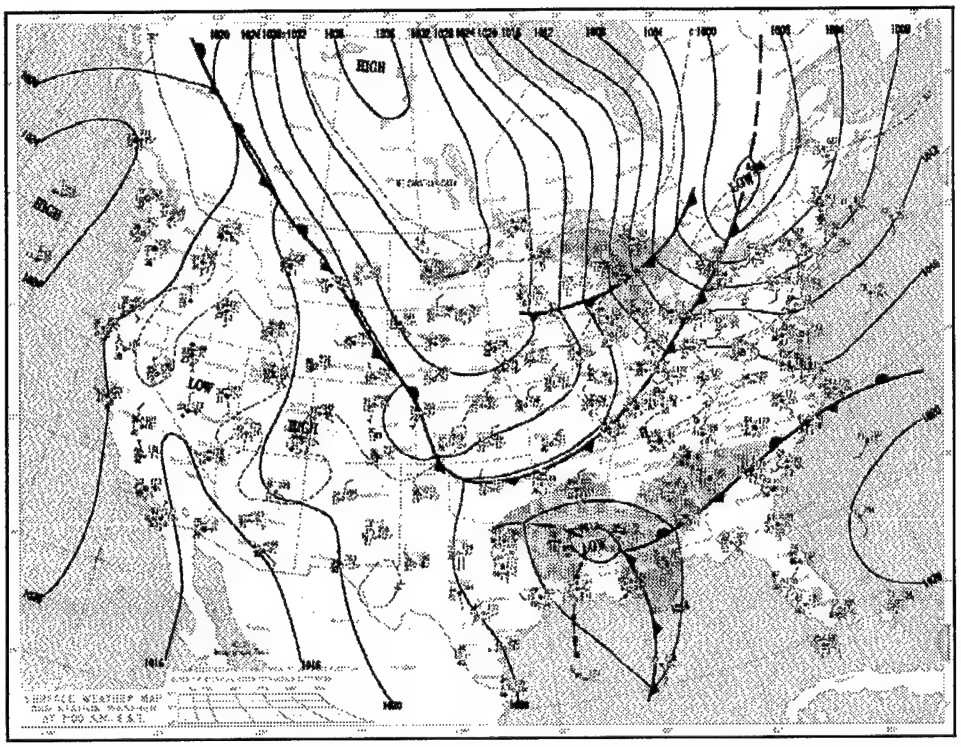

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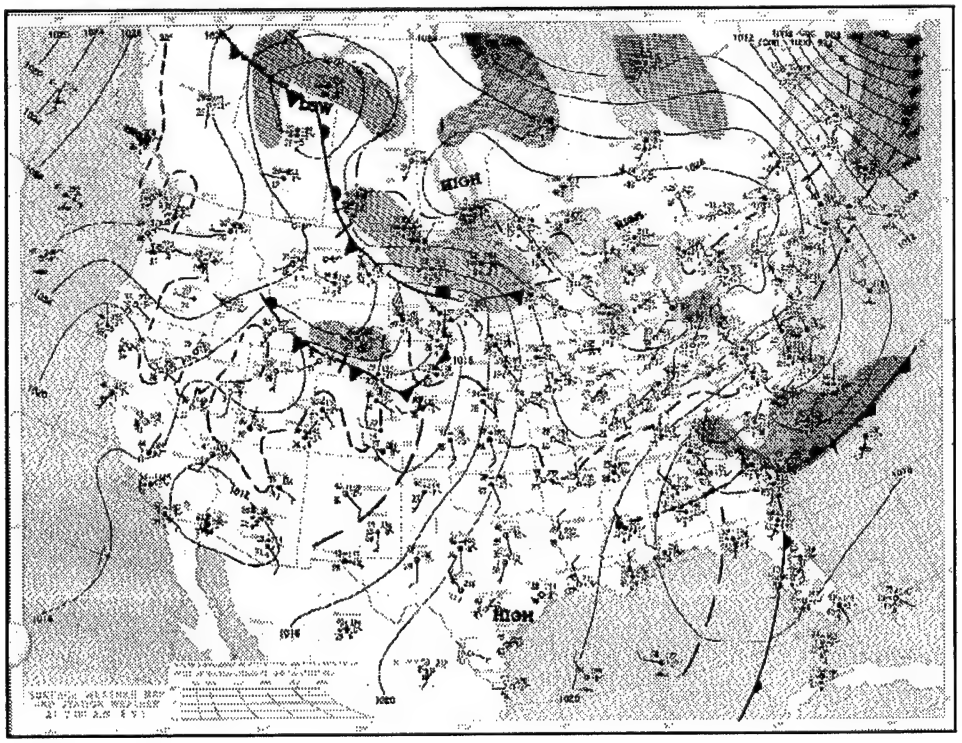

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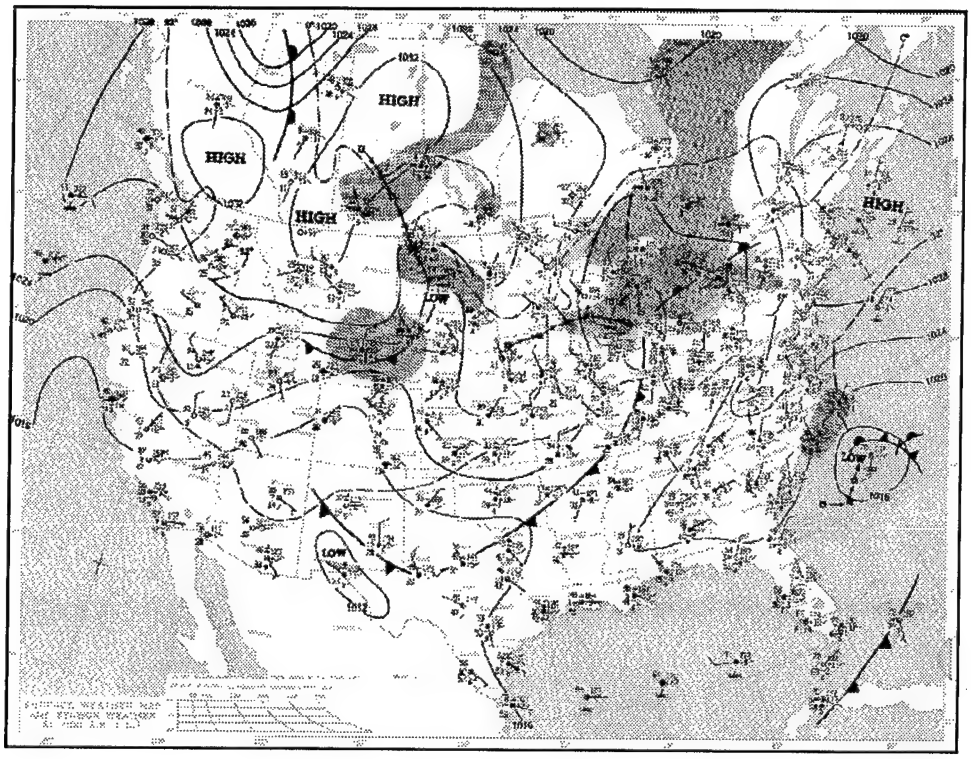
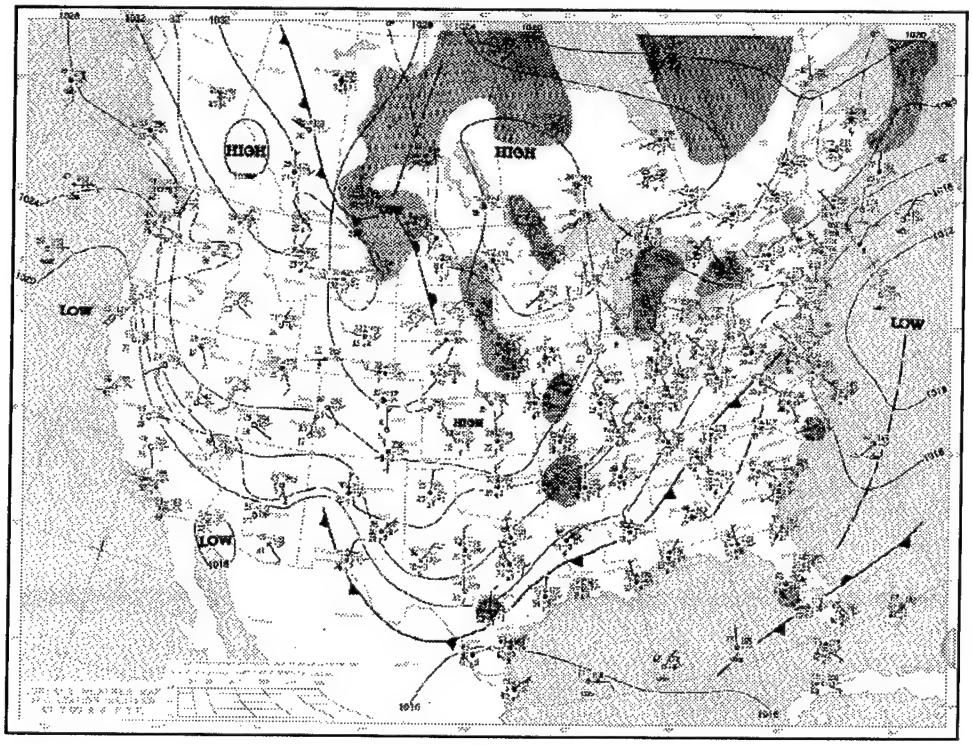


Figure F13. 24 February 1991



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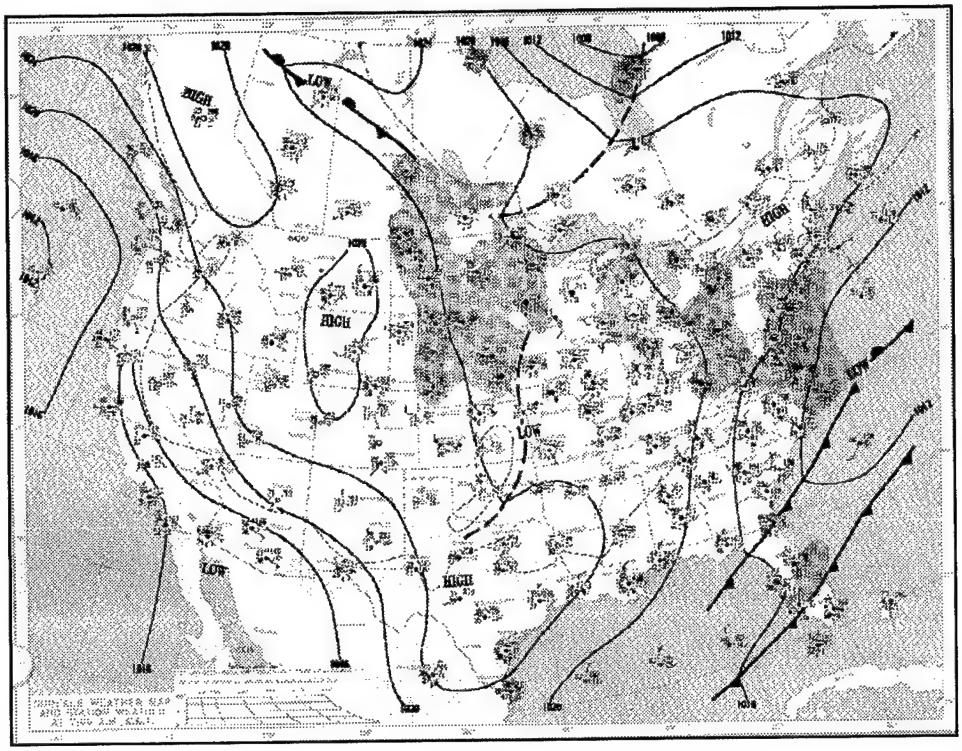
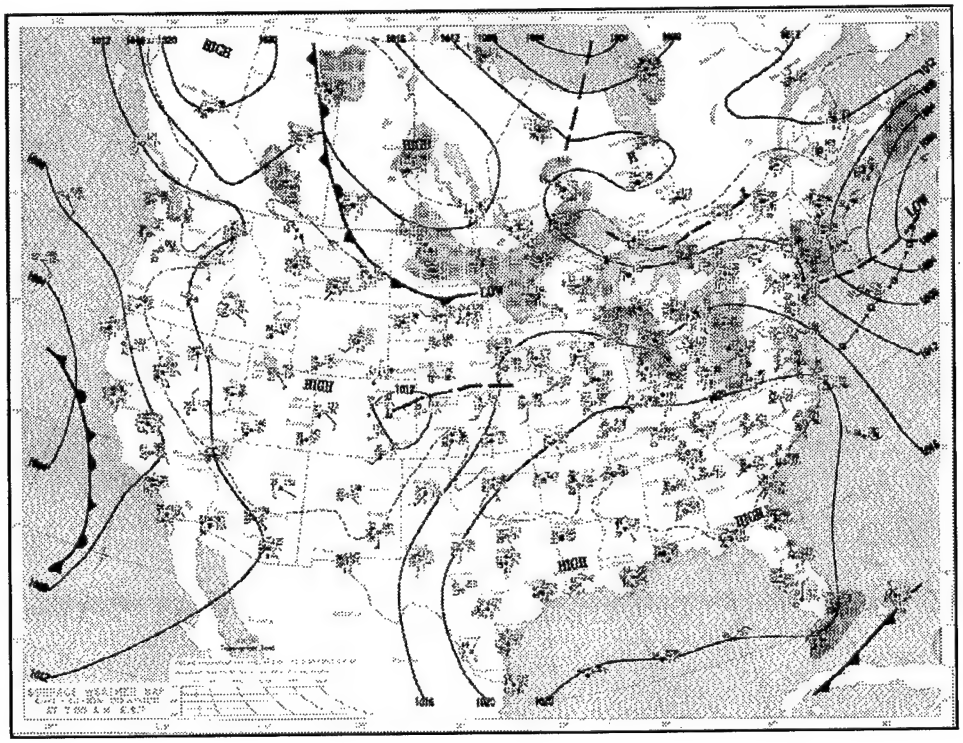


Figure F15. 26 February 1991



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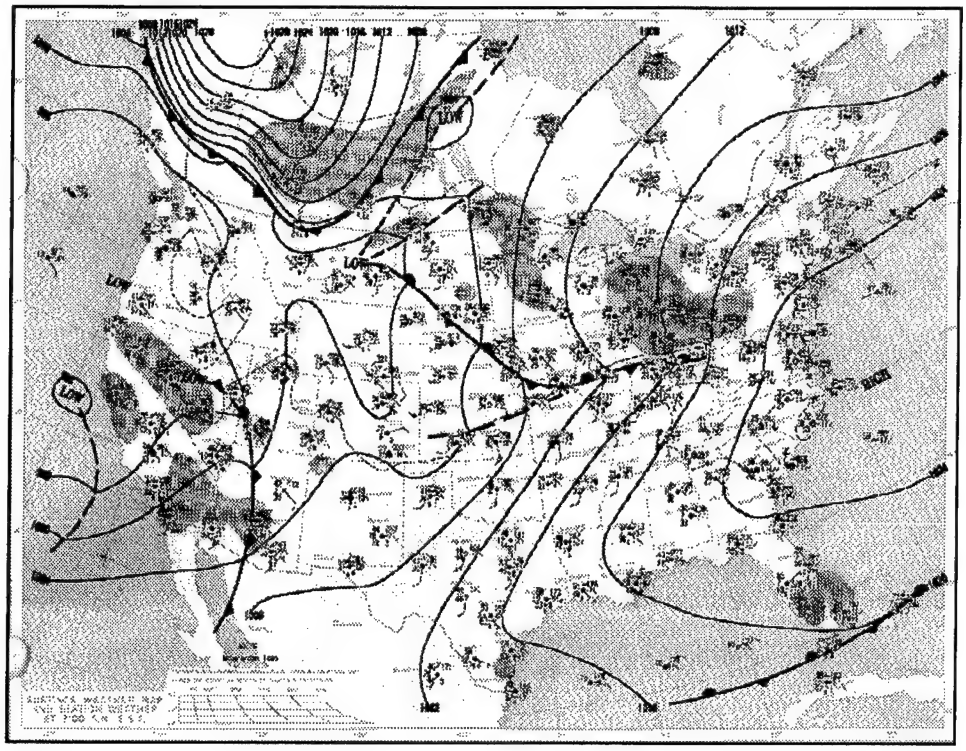


Figure F17. 28 February 1991

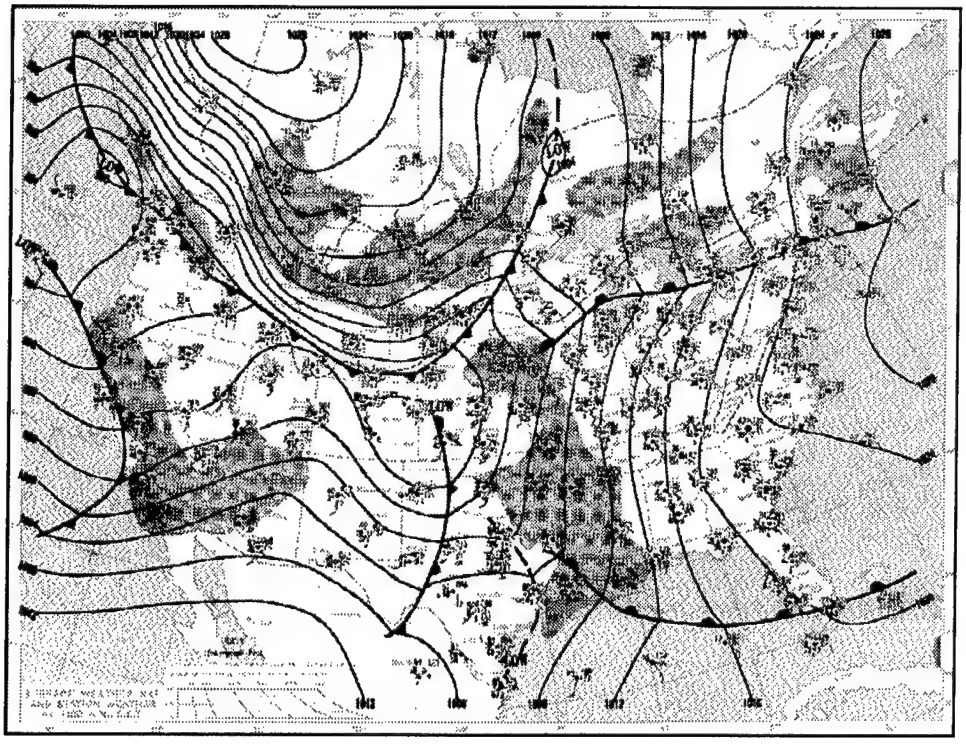
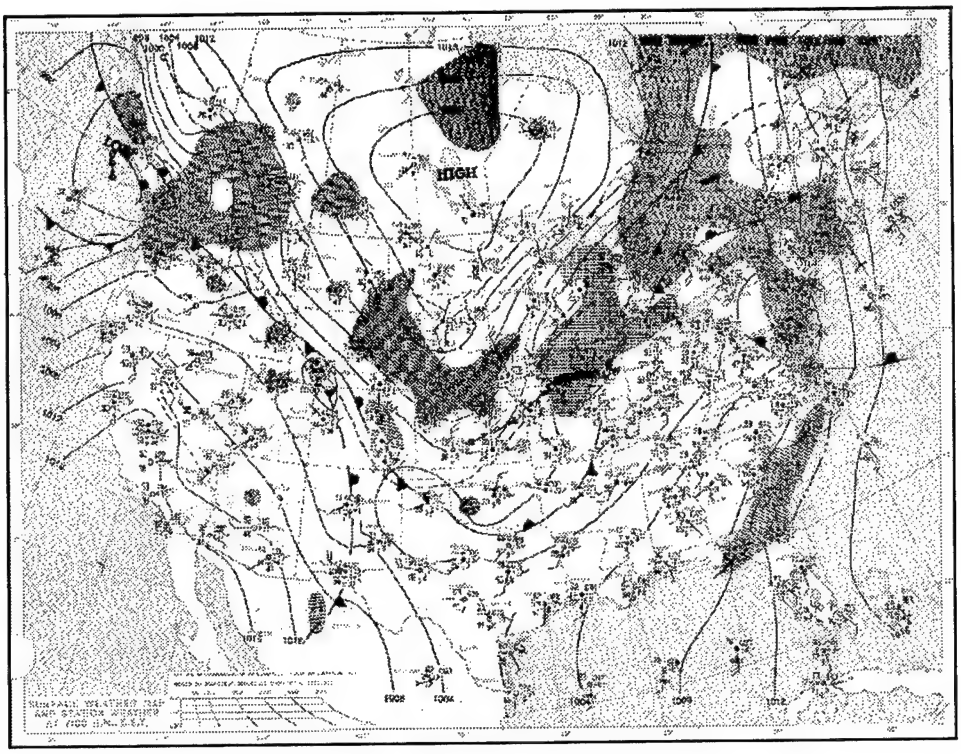


Figure F18. 1 March 1991



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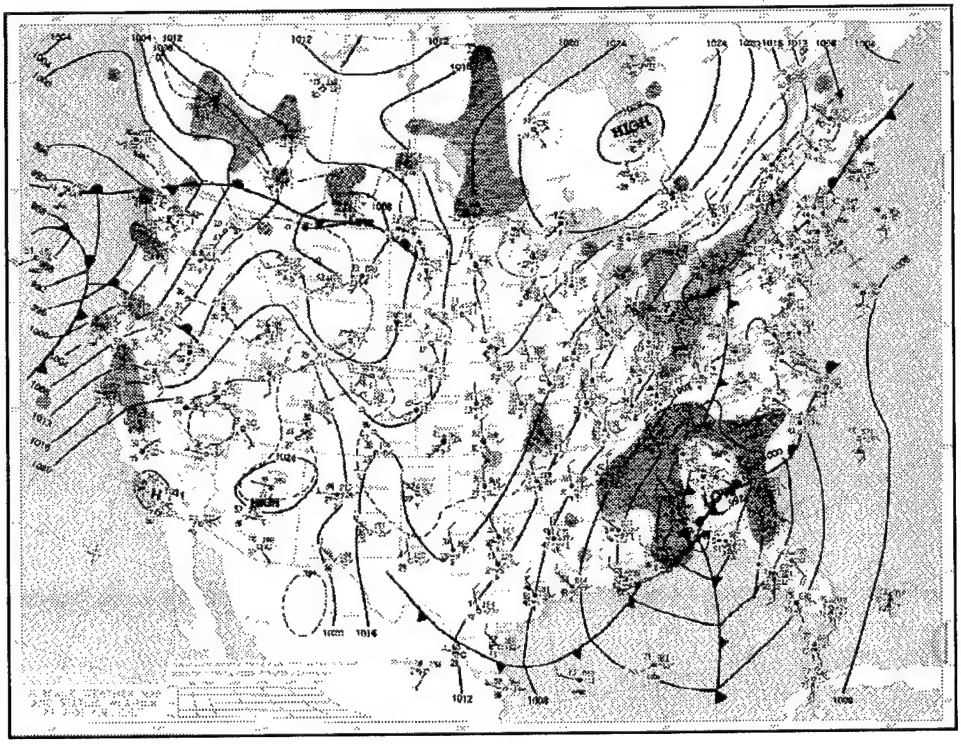

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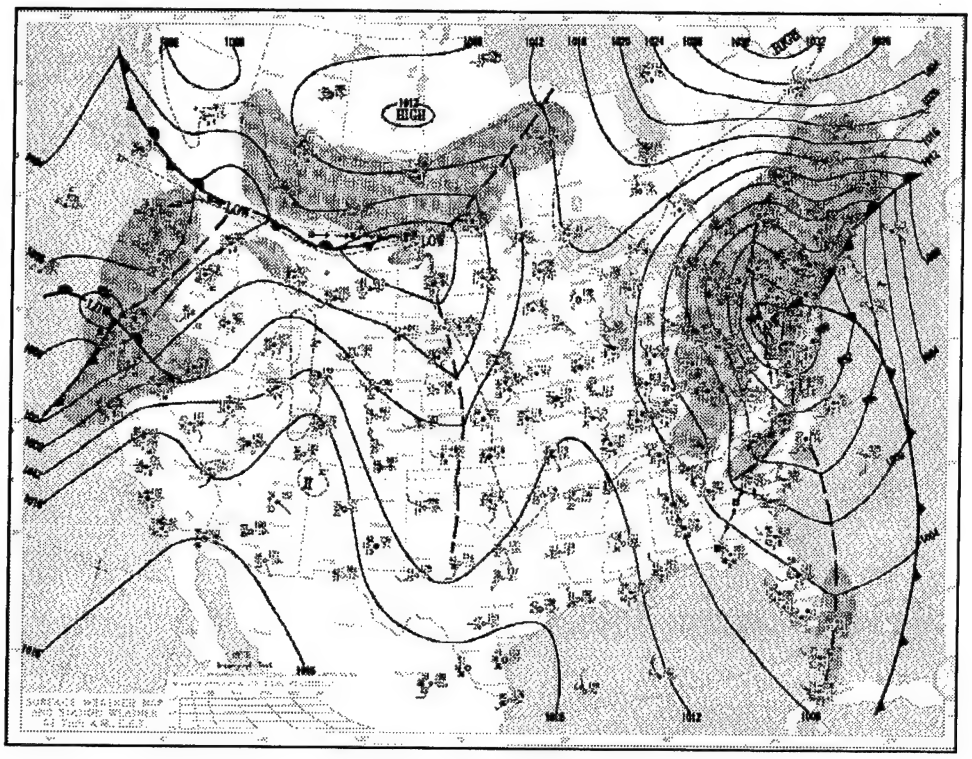

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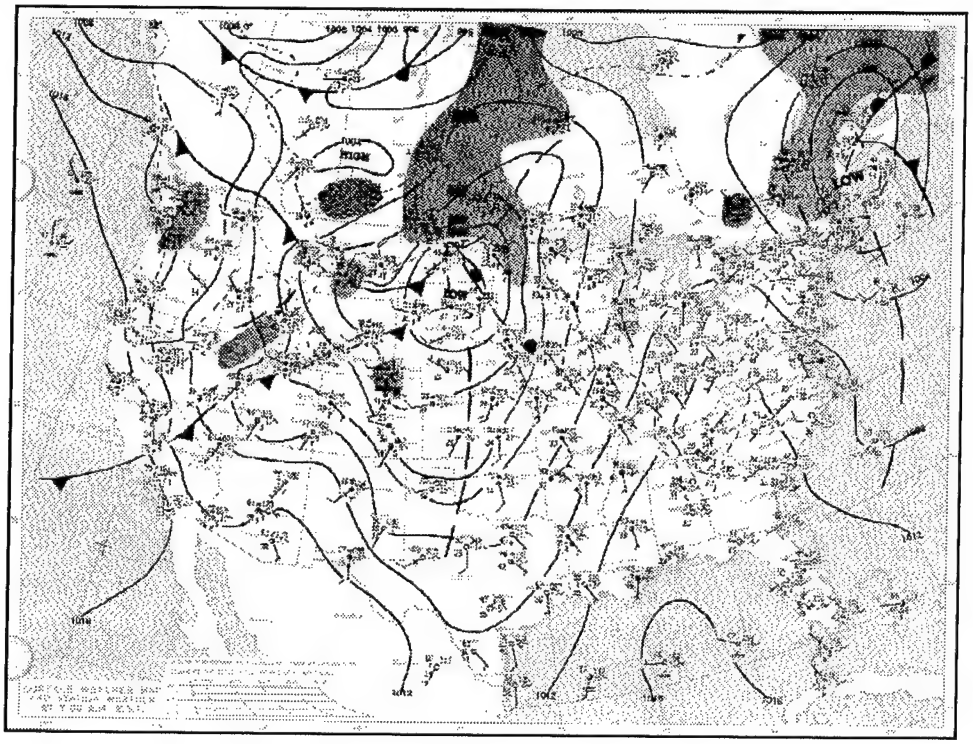

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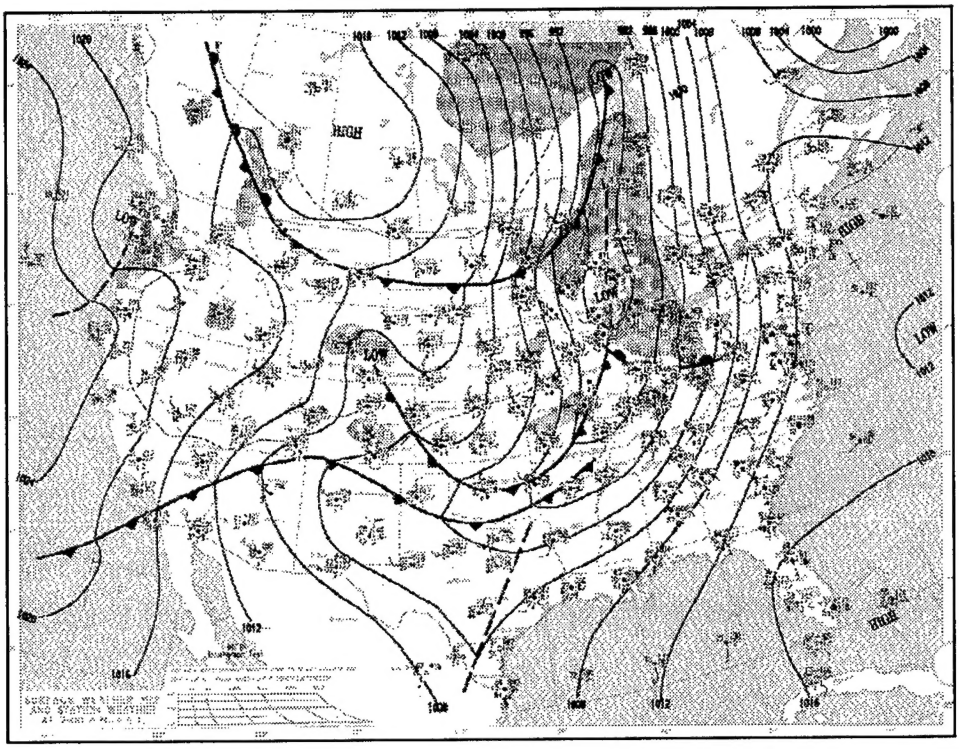

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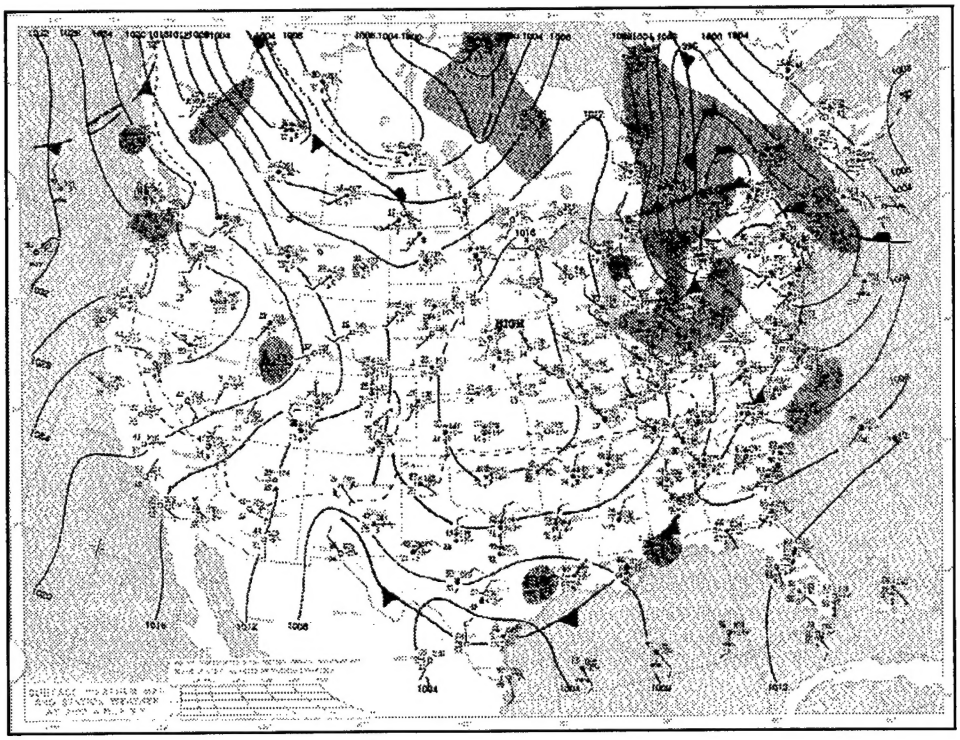

Figure F24. 7 March 1991

Appendix G
Notation

A	Wave form amplitude
c	Speed of light
D_o	Normalization constant
E	Energy spectrum
E_o	Wave height variance
E^*	Nondimensional energy
f	Frequency, hertz
f^*	Nondimensional frequency
F	Directional wave-height variance, or energy, spectrum
g	Acceleration of gravity
H	Mean altitude, aircraft altitude
Hs	Wave height
k	(Radian) wave number
K	Wave number, cycles per meter
L_y	Lateral, l-sigma, antenna footprint dimension
md	Mean direction
MSS	Mean square slope
MSS_1, MSS_2	Principal mean square slope components

pd	Peak direction
R	Slope anisotropy aspect ratio (MSS2/MSS1)
s	Spread parameter
SWH	Significant wave height
t_o	Time of return from the mean sea surface (epoch)
Tp	Peak period
U_{10n}	Equivalent neutral wind speed at 10-m-level
W	Wind speed
$W(t)$	Average altimeter power return wave form
X*	Nondimensional fetch
α	Measurement sensitivity coefficient
$\Delta\phi$	Half-power directional spread
$\Delta\phi_{iso}$	Isotropic limit for first harmonic half-power spread
θ_c	Effective incidence angle
σ	Leading edge wave form parameter
σ_b	Antenna beam width parameter
σ_p	l-sigma radar pulse width
τ	Trailing edge wave form parameter
ϕ	Azimuth of the antenna
ϕ_1	Major axis direction
ϕ_o	Mean direction

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Frederick C. Jackson

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13. ABSTRACT *(Maximum 200 words)*

The Surface Wave Dynamics Experiment (SWADE) was a large-scale, multi-platform surface wave experiment that was conducted in the southern mid-Atlantic Bight (MAB) off the U.S. east coast during the fall and winter of 1990-1991. The purpose of the experiment was to study the dynamics and evolution of the directional wave field in response to meteorological forcing making use of recent advances in analysis and in situ data collection, numerical wave modelling, and airborne remote sensing. Of the remote sensing instruments participating in the SWADE, the National Aeronautics and Space Administration's Radar Ocean Wave Spectrometer (ROWS) instrument was the most heavily exercised. ROWS collected approximately 45 hr of high-resolution, directional wave spectra and wind speed data on more than a dozen aircraft flights before, during, and after the last intensive observation period (IOP-3). Processed data include 158 spectra files and 88 wind speed files for 12 flights conducted over the period 12 February-7 March, 1991. This report presents all ROWS data that have been processed to date for the SWADE mission. Buoy and model data collected during the "St. Valentine's Day" frontal episode (14-16 February, 1991) are also presented.

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